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Halifax, Nova Scotia
February 17-26, 2003

Jake Rice and Denis Rivard
Chairpersons

Fisheries and Oceans Canada
200 Kent Street
Ottawa, K1A 0E6

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Foreword

These Proceedings record the discussions held at the Zonal Assessment Meeting – Atlantic Cod during February 2003. They were prepared by volunteer rapporteurs. Their purpose is solely to archive the activities and discussion of the meeting, including research recommendations, and to provide a place to formally archive minority opinions. They are not a complete verbatim record of all discussions, but do attempt to capture all major concerns raised and issues discussed. As such, interpretations and opinions presented as well as some questions raised, may be factually incorrect or misleading, but are included to record as faithfully as possible what transpired at the meeting. No statements are to be taken as reflecting the consensus of the meeting unless they are clearly identified as such. Furthermore, additional information and further review may cause the meeting to change its decision on a point where tentative agreement had been reached. Therefore, only the Stock Status Reports, which contain the consensus decisions of the meeting, should be used as sources of information on the status of the resources assessed.

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Abstract

Approximately 75 participants from federal and provincial government, FRCC, the fishing industry, universities and invited experts convened for a zonal assessment of Northwest Atlantic cod stocks on February 17-26 in Halifax, Nova Scotia. The purpose of the meeting was the peer review of the status of the following cod stocks: Southern and Northern Gulf, Labrador Shelf and Northern Grand Banks(northern cod) and Eastern Scotian Shelf. Also the participants reviewed the possible reasons for lack of recovery since the moratoria.

Projections of stock trajectories in the coming five years suggest that some stocks may decline further even in the absence of fishing, and no stocks are likely to show more than marginal increases. All stocks are projected to decline further at current exploitation rates.

Taken together, these factors strongly suggest that there will not be a prompt recovery in any of these stocks.

RÉSUMÉ

Un groupe d'environ 75 personnes, constitué de représentants du gouvernement fédéral, de gouvernements provinciaux, du CCRH et de l'industrie de la pêche, ainsi que d'universitaires et d'experts invités, a participé à une réunion d'évaluation zonale des stocks de morue de l'Atlantique nord-ouest qui a eu lieu du 17 au 26 février à Halifax, en Nouvelle-Écosse. L'objectif de cette réunion était d'évaluer l'état des stocks de morue suivants : stocks du sud et du nord du golfe du Saint-Laurent, du plateau continental du Labrador, du nord des Grands Bancs (morue du nord) et de l'est du plateau néo-écossais. Les participants ont également examiné les raisons qui peuvent expliquer l'absence de rétablissement depuis l'imposition des moratoires.

Les prévisions de l'évolution des stocks au cours des cinq prochaines années suggèrent que certains stocks pourraient s'affaiblir davantage même en l'absence de pêche, et qu'aucun stock ne devrait connaître une hausse d'effectif importante. Si les taux d'exploitation actuels sont maintenus, l'effectif de tous les stocks devrait baisser davantage.

Ensemble, ces facteurs suggèrent fortement qu'aucun de ces stocks ne se rétablira rapidement.

1.0 Introduction

A zonal assessment of the cod stocks in the Gulf of St. Lawrence (3Pn4RS and 4TVn), northern cod (2J3KL), and cod on the Eastern Scotian Shelf (4VsW) was held during February 17-26 in Halifax, Nova Scotia. This meeting was held as a formal, scientific peer review to assess the state of these cod stocks. The Agenda for the meeting is provided in Annex 1.

The Terms of Reference (see Annex 2) charged the participants to address three objectives: 1) assess the status of the four cod stocks; 2) consider possible reasons why these stocks have failed to recover since the moratoria; and 3) review medium-term simulations for these four stocks.

There were approximately 75 participants, which included DFO scientists, fisheries managers, participants from the fishing industry and universities, and technical experts from Canada, United States, U.K. and Iceland. The list of participants appears in Annex 3.

1.1 Status of the Four Stocks

Stock status was assessed based on data from research vessel and sentinel surveys, pre-recruit surveys, acoustic surveys, tagging studies, surveys of fish harvester's views on resource status, commercial and recreational fisheries landings and catch rates from the commercial fishery, where available. New information on biological parameters was reviewed, together with other information on the physical or biotic environment considered important to interpreting trends in indicators of stock status.

For each stock, the meeting provided estimates (with associated uncertainties) regarding spawning and fishable biomass, total and fishing mortality, exploitation rate, and other stock characteristics determined to be informative about stock status and/or consequences of management options. When it was not possible to estimate some of the key stock characteristics listed above, providing other indicators of stock status that could be informative to management was particularly important.

For Northern cod, Northern Gulf cod, and Southern Gulf cod, the meeting advised on the risk that the stock would fall to or below the conservation (limit) reference points for spawning stock biomass (SSB) identified at the Gadoid Reference Point Workshop in November 2002. For Eastern Scotian Shelf cod, reference points were calculated using the methods identified at the November workshop, and the risk of the stock being at or below these points was identified.

1.2 Reasons for Lack of Recovery

An inventory of over 40 hypotheses for why these stocks have not recovered to historic levels in the past decade was previously developed by a Planning Group. Through discussion and preliminary consideration of available data, the list was consolidated and organised into groups of related hypotheses (see Annex 4). Some hypotheses can only be addressed on the zonal scale, bringing together such data as are available from several places through the Atlantic Zone. Other hypotheses can be addressed thoroughly for only one stock, and weakly, if at all, for the other stocks. Still others may not be able to be addressed at all, due to the absence of relevant data.

The meeting considered the alternative hypotheses in full awareness of the limitations of the data and, in some cases, the analytical methods. The meeting operated in an advisory mode, evaluating the *weight of evidence* that, with regard to the weak recovery of these stocks, an hypothesised factor:

1) *could have been important.*
2) *could have been a factor but probably made a minor contribution.*
3) *was unlikely to have been a factor* or *at most made a minor contribution.*
4) *is not sufficiently documented or understood to make a conclusion about its role.*

Few, if any, of the hypotheses can be definitively rejected as having no role whatsoever in the poor recovery, nor can a specific degree of responsibility for failure to recover be assigned to any single possible causal factor.

The importance of the hypothesised factors varied for different stocks. However, for hypotheses that could be addressed thoroughly with data from only one or two stocks, particular attention was given to generalising the results to other stocks, and the strength of any justification to reject this.

For all hypotheses in classes 1 and 2 above for each stock, the meeting considered if there was any reason to expect the factor to change its effect in the near future (3-5 years), and to the extent possible, specify the reason(s) for such expectations. Where there is no cause to expect a change in a factor, the meeting assumed that the best indicator of the near future is the present and recent past.

1.3 Projections

The Fisheries Resource Conservation Council (FRCC) had requested medium-term stochastic simulations for the four stocks. “Medium-term” has been interpreted to be a maximum of 5 years. These simulations were carried out using common data treatments (ie number of years for averaging) to ensure consistency for the four stocks.

2.0 Stock Assessments

The following section is a summary of the discussions that occurred following the presentations. The conclusions summarize some important points contained in the Stock Status Reports (SSR) produced for each stock. The full versions of the SSR are found in Annex 5.

2.1 Northern Cod - 2J3KL

The status of the 2J+3KL cod stock was assessed based on data from research bottom-trawl surveys, sentinel surveys, prerecruit surveys, acoustic surveys in specific areas, tagging studies, a questionnaire completed by fish harvesters, catches from the commercial and recreational fisheries, and catch rates from the commercial fishery.

Discussion

Rapporteur: Peter Shelton

G. Lilly presentation – history, current data and analysis

It was asked whether the late survey in 2002/2003 could affect the fall RV trawl index given seasonal patterns of fish distribution, and if so in which direction.

The response was that historically one would have expected more fish to be offshore in the survey strata later in the season (i.e. January vs. November).

It was noted that this would tend to lead to an overestimate, in comparative terms, as a consequence of fish moving out of the inshore and into the survey strata.

The presence of fish in regulatory area of NAFO (i.e. outside 200 n. miles) in the spring survey data was mentioned and it was suggested that there might be increased vulnerability to foreign factory freezer vessels at this time. It was also noted that vessels boarded and inspected in the regulatory area or those that came into Newfoundland ports for repair after fishing in the regulatory area sometimes had significant amounts of cod products on board (fillets, livers etc.) but that this was ascribed to cod caught in the Barents Sea earlier in the voyage.

A number of questions were posed regarding the survey trawl gear conversions that were applied to obtain the "Campelen equivalent" index time series. In particular, whether in some cases small numbers were being converted from Engel catches to Campelen equivalent catches, and that in some cases there were zeros which could not be converted. It was also questioned the whether or not the differences between vessels was taken into account.

It was confirmed that small numbers were involved in some age classes: in the young ages in the historic Engel data and in the older ages during the comparative fishing exercise between Engel and Campelen data. Warren fitted a model to the comparative fishing data in order to get length based conversion factors (available in a NAFO SCR Doc) and this seemed to work quite well but that there was no way around the zeros in the historic data. With regard to vessel differences, this was not accounted for in the conversions – instead the approach was to attempt to ensure that the Teleost only fished strata that were previously fished by the Gadus and that the Templeman continued to fish only those strata which it had previously fished using the Engel trawl.

G. Rose presentation - acoustic data from Smith Sound, Hawke Channel and the Bonavista corridor/Tobin's Point areas

It was questioned whether there was any evidence of significant over-wintering aggregations in Bonavista Bay in recent years. Rose said that Bonavista Bay is covered in his surveys but no significant aggregations (in the thousand or more tons range) have been noted. This was not to say that there were not some scattered fish amounting to biomass levels in the 10's of tons range.

It was asked how the acoustic targets that existed in the "dead zone" were accounted for in the biomass estimates. Rose explained that these were accounted for in the method through straight linear extrapolation to the bottom. These methods are peer-reviewed and available in the primary literature.

It was asked whether Rose had carried out any quantification of the contribution of the spawning from the 1994 yearclass in the Hawke Channel area to the 1998 yearclass observed in the Anderson pelagic 0-group and juvenile data. Rose responded that given that the 1994 were dominant at the time, it seemed a logical conclusion, but he has not quantified the contribution.

Though one observation indicated that only 10% of 4 year olds are mature so a significant contribution would be unlikely, Rose contended that in the Hawk Channel area his data indicated that about 50% of the 3 and a half-year-olds were mature (published data?).

D. Maddox-Parsons presentation - Sentinel Survey Data

It was asked why the 31/4 inch mesh gillnet data are used in the recruitment model but not considered an index in the calibration of the SPA. The answer was that, whereas the recruitment model attempts to use all the data and to apply inverse variance weighting, the SPA applied to northern cod gives equal weighting to the indices and it is considered that the low amount of data reflected in the small mesh gillnet series is inadequate for tuning the SPA at the present time.

J. Brattey and N. Cadigan presentation - Cod tagging data and analysis

It was questioned what factors were contributing to the estimates of low exploitation in offshore 3Ps and conjectured that this might be a consequence of lower returns of the high reward tags? Brattey responded that returns are less from offshore 3Ps tagging and consequently the uncertainty is higher, however reporting rates do not appear to be that much different from the inshore.

The opinion was expressed that the high biomass estimates for 3KN in 2001 is a little difficult to believe, particularly given the low amount of tagging in that area in that year.

It was questioned whether the authors were advocating the biomass estimates in the summary paper. Cadigan clarified that they were advocating the use of a higher value of M. It was asked if this was because of the increasing residual problem over time and this was confirmed.

It was queried how the current estimates compare with those in the 2001 assessment and whether or not the protocol of presenting estimates based on both the old and new model should be followed. The meeting considered this was advisable if time allowed.

B. Healey presentation- Year class strength model

It was suggested that the model estimates did not show up what were thought to be strong year classes and the individual indices did not track year classes very well.

It was noted that the year class model was an attempt to take into account all the available data on fish age 0 to 3 in a rigorous manner. The survival of year classes beyond age 3 and their subsequent contribution to commercial fisheries would in part be a consequence of initial year class strength and subsequent mortality both by the fishery and predation by seals.

P. Shelton and D. Stansbury presentation – SPA estimates

One participant agreed with the estimates of sustainable exploitation rate that were presented based on a simple model. He expressed the view that attention should be given to developing a migration SPA for northern cod to take into account the sub-stock structure and movements that characterized the area. He enquired whether or not there was any evidence that the inshore component was fished out early on in the history of the fishery.

Shelton agreed that a form of migration SPA might be very useful in the context of northern cod and that there were some precedents in the primary literature that should be examined.

It was noted that there was some evidence that inshore components might have been fished to low levels following the introduction of gillnets and longlines.

Another observation noted that much of the recruitment early on in the stock assessment series came from 2J in which weights are lower and consequently the value of a recruit in terms of contributing spawner biomass is worth less.

It was noted that the CV's on the inshore SPA were very high - 0.94 on the 3's – and asked whether or not one could assign a PR to constrain the estimates and increase the precision.

Darby explained that in his SPA (XSA) he approached this problem using shrinkage and by not going out to older ages.

It was noted that the data on northern cod in the inshore was coherent – the sentinel and RV data are saying basically the same thing.

However, it was pointed out that the catch in 1994 constituted significant amounts of offshore fishing and it was agreed that further SPA analyses would only use catch data from 1995 onwards.

Stansbury agreed and suggested that this would not change the overall trend.

Discussion of final runs required for 2J3KL cod

With regard to the tagging model there was a discussion regarding re-running the estimates using a higher M to reduce the residual pattern. It was noted that there was no evidence that fish were particularly vulnerable to recapture in the period immediately following tagging – in fact fish appear less exploitable immediately after tagging.

It was suggested that one could look at catch by week to see if this is the case – i.e. the number of tags returned as a function of week at liberty. It was noted that seal predation on adult cod was additional support for introducing a higher M value. Following the discussion it was agreed to carry out the tagging at higher M – selected on the basis of the residual pattern. It was also agreed that the SPA would use the same value of M.

Also it was suggested to look at the biomass estimates by the increasing micro – areas, compare migratory and non-migratory estimates to see how they stack up.

Other 2J3KL cod issues

It was noted in discussion that potentially important contributors to the high levels of natural mortality that are occurring on northern cod included, in addition to harp seals, other marine mammals, most notably hooded seals and piscivorous whales.

Conclusions

The main conclusions were as follows:

- Research bottom-trawl surveys in both fall and spring indicate that the biomass of cod remains extremely low. The average trawlable biomass from fall surveys during 1999-2002 is 28,000 t, which is about 2% of the average during the 1980s. Hydroacoustic estimates within two regions of the offshore (Hawke Saddle (2J) and the saddle along the 3K/3L boundary) were considered highly uncertain but suggest a combined biomass of less than 20,000 t. Hydroacoustic surveys in January in Smith Sound (Trinity Bay) provided average indices of biomass that increased from 1999 to a peak of 26,000 t in 2001 and then declined to 20,000 t in 2003. Indices of stock size from sentinel surveys, which are conducted with fixed gear in inshore waters, increased from 1995 to 1997-1998 and have since been declining.

- Estimates from the fall research bottom-trawl data indicate that mortality has been extremely high in the offshore since the moratorium and few fish survive beyond age 5. Results of tagging experiments indicate a harvest rate close to 20% in 2002 associated with a reported catch of 4,200 t. This harvest rate is in percent of exploitable biomass (approximately ages 4+), which was estimated to be 22,000 t in the inshore regions of 3KL. The exploitable biomass estimates increased during 1999-2001, but declined sharply in 2002. Most of the cod caught in southern 3L are thought to overwinter off southern Newfoundland (3Ps). The tagging studies provided evidence of natural mortality of 0.8 in 3K and 0.4 in 3L. These estimates are considered to be independent of unreported catch.

- Catch rates from commercial logbooks declined from the opening in 1998 to the present. Catch rates in sentinel surveys and commercial fisheries have been consistently low in 2J and northern 3K. Since the fishery opened in 1998, catch rates have declined in both southern 3K and southern 3L, and have remained high only in northern 3L, most notably in southern Bonavista Bay and northern Trinity Bay. The opinions of fish harvesters, as recorded in responses to a written questionnaire sent to fish harvester committees throughout the stock area, are in general agreement with the above trends.

- A sequential population analysis (SPA) was conducted based on those cod in the inshore since the mid-1990s. The analysis incorporated catches during 1995-2002 and indices from the sentinel surveys and research vessel inshore strata. SPA estimates indicate that spawner biomass in the inshore increased from 1995 to 41,000 t in 1998, but has subsequently declined to only 14,000 t at the beginning of 2003. The estimate of 4+ biomass at the beginning of 2003 is about 32,000 t. Fishing mortality on older age classes has been increasing and is currently at approximately 35%, a level comparable to levels estimated during the stock collapse in the late 1980s and early 1990s.

- Both the SPA and a recruitment model indicate that the 1999 and 2000 year-classes are stronger than other year-classes since the mid-1990s, but are very weak compared to historic levels.

- The SPA indicates that the inshore spawner biomass has been decreasing since 1998 when the fishery reopened. Deterministic projections indicate that the stock will grow slightly in the short term as a consequence of the incoming recruits, but will decline thereafter if exploitation rates remain at current levels. Projections also indicate that even without fishing the spawner biomass will not grow during the next decade to the level reached in 1998, under the assumption that stock productivity does not increase above present levels.

- The information on feeding by seals and trends in the harp seal population indicate that predation by seals is a major factor contributing to the high total mortality of cod in the offshore and the high natural mortality of adult cod in the inshore. Consumption of cod by harp seals in 2000 is estimated from diet studies to have been about 37,000 t (95% confidence interval of 14,000 – 62,000 t). Most cod represented in such studies are small. Harp seals also prey on large cod by consuming only soft parts, and such predation has been frequently observed. Predation by hooded seals on cod has not been measured but is potentially large.

- When the spawner biomass in the stock as a whole approaches 150,000 t, the available data will be reviewed to determine appropriate spawner biomass limit reference points in keeping with a precautionary approach. Based on historic data, it is anticipated that appropriate conservation limit reference levels will be set at levels greater than 300,000 t for the stock as a whole. Recovery of spawner biomass to this level is expected to take many years. While the stock remains below this level, there is a high likelihood that the productivity of the stock will remain impaired.

2.2 Northern Gulf Cod - 3Pn4RS

The status of the 3Pn,4RS cod stock was updated based on additional data from research vessel and sentinel surveys, industry-based tagging, industry survey of fish harvesters views on the status of the resource, commercial and recreational landings, and the sequential population analysis.

A December 20th 2002 letter to DFO and the Chairman of the FRCC from Mr. Alastair O'Reilly, President of the Fisheries Association of Newfoundland and Labrador (FANL), notes, in particular, the 3Pn4RS/3Ps mixing issue, the high level of uncertainty with respect to the validity of the data used and the interpretation of the results of the various index fisheries and the fact that the stock assessment model does not count for the widespread (in Mr. O'Reilly's view) discarding at sea practices of the gillnet fishery. FANL also sent a position paper to officials raising many points and questions regarding this stock (see Annex 6 for both documents). His letter was provided to key DFO scientists prior to the ZAP session to aid in planning and the position paper was tabled at the ZAP so that all participants would be aware of some of the issues that needed to be addressed.

Both the All-Party Committee report (APC) and Mr. O'Reilly's letter are critical of the lack of funding for science. One of the APC's recommendations specifically states that the "Government of Canada must increase the level of funding to DFO for scientific research". Mr. O'Reilly's notes a number of cases where specific research has not been carried out due to inadequate funding.

During the present assessment, both external scientific reviewers and industry raised a number of technical questions echoing the issues and concerns raised by All-Party report and the President of FANL.

2.2.1 Presentations on the State of the 3Pn- 4RS stock

Rapporteurs: Jean Landry and Martin Castonguay

2.2.1.1 State of the Stock (Alain Fréchet)

Landings and fishery description

- Total landings for 2002 (preliminary data) added up to 6246 tons, with a TAC of 7000 tons. These include 34 tons for sport fisheries.
- The only commercial fishing activities authorized in 2002 were those with fixed gears. The main cod landings occurred from July to October. These landings were mainly from gillnet fishery in division 4S and from longline fishery in 3Pn. Landings were more evenly distributed between both types of gears in division 4R, but gillnet fishery was nevertheless more significant.
- In the spring of 2002, a specific area offshore of St.Georges Bay was closed to fishery for a 10-weeks period in order to protect cod during spawning. This area was delimited based on data of four former scientific surveys.

Analysis of catches

- Main landings were individuals from 6 to 9 years-old. However, it was noted that contrary to last years the 2002 fishery was highly dependent on the 1993 age group (9 years).

- The increase in weights at age for commercial fishery compared to that observed in the beginning of the 1990s can be partly explained by the fact that winter fishery occurred at that time, but has been interrupted for a few years.

Discussion

What is the level of reliability of commercial fishery statistics? Questions were raised concerning the decrease of landings for recreational fishery.

Answer: In general, fishery statistics are more reliable than in the past. The reasons for the decrease in catches for recreational fishery are related to a shorter fishing season and a lesser number of licences, which dropped from 30 to 15 in 2002.

An industry representative mentioned that a significant number of cod mortalities are not accounted for — accidental catches from witch flounder fishery as well as discarding from cod commercial fishery with gillnets. The impacts of this problem on stock evaluation (sensitivity runs) will be evaluated later during this review.

2.2.1.2 Mixing of 3Pn-4RS Stock with that of 3Ps (Martin Castonguay)

Preliminary results of various on-going surveys on this matter were presented. The first results presented were for the cod tagging programme in 3Pn4RS. The main conclusions from this study were as follows:

- Mixing of the 3Pn4RS stock cods does not only occur with unit areas 3Psa and 3Psd, but involves 3Ps as a whole. Moreover, it seems to occur all year round.

- Mixing seems more significant with 3Pn than 4RS. Indeed, 17% of recaptures in 3Ps are cods tagged in 3Pn, these proportions being respectively of 10% and 5% in 4R and 4S.

- Recaptures in 3Ps of cods tagged in 3Pn and 4R is less significant when tagging is made during spawning (from May to July).

The results of a study on the seasonal evolution of sexual maturity of cods in divisions 4R and 3Pn and in unit areas 3Psa and 3Psd were presented. The highlights of this study were as follows:

- A few spawning females are found on Burgeo Bank (3Psa + 3Psd) at any time of the year. That would indicate that the high percentage of maturing females found in this area reproduce elsewhere (in 4R?).

- A high percentage of females in recovery are observed in 3Pn, 3Psa and 3Psd in May, which suggests that these females reproduce elsewhere.

Other studies were initiated or should be undertaken on this issue. The analysis of trace elements in otoliths which will be completed in a near future from maturing and spawning cod samples collected in Burgeo Bank and in division 4R is mentioned. Another project involving acoustic tags could be initiated in 2004 to collect additional information concerning the mixing of these stocks.

Discussion

Did former studies on genetics make it possible to confirm that two different stocks exist?

Answer: The results of these studies did not make it possible to differentiate the stock of the north of the Gulf of the stock of the south, even if these stocks are considered as different. So, we believe that the otolith trace element technique could be more promising for the differentiation of these stocks.

NOTE: At 11:15 AM, the meeting was adjourned to the following day due to a power failure.

2.2.1.3 Cod Condition Review (Johanne Gauthier)

Since 1994, the evaluation of cod condition has been made as a part of a monitoring program whose goal is to determine the general health of the stock of the north of the Gulf. A specific evaluation of the condition is done in August during the Alfred Needler scientific mission (1995-2002). Four indexes are evaluated: the Fulton index (Ksom), which provides a specific health status (somatic length-weight relationship); the hepatosomatic index (HSI), which corresponds to lipid energy reserves (relationship between liver weight and somatic weight); the liver water content, which provides information on lipid reserves, and finally the percentage of water in muscles, which reflects the level of the protein reserves (Dutil et al. 1995).

The Fulton and hepatosomatic indexes are also evaluated all over the year through fixed gear sentinel fisheries in Newfoundland and the North Shore (1995-2002). The evaluation of the condition during mobile gear sentinel fisheries of July and October (1995 -) was stopped in 2000. The monitoring program used three new mobile gear surveys from sentinel fisheries of 2002 to collect data on cod condition during the winter.

The main results concerning cod condition were as follows:

- The annual variations of Fulton and hepatosomatic indexes confirm the general pattern known for cod, that is to say a minimum value for indexes during the spring and an increase during the summer to a maximum in the fall.
- The minimal spring values observed each year are considered normal for the stock of the north of the Gulf, but it is nevertheless a critical period where cod is subjected to a

significant physiological stress. Moreover, these conditions would be probably regarded as abnormally low for several cod stocks other than that of the north of the Gulf.

- The 3Pn-4RS cod condition is considered good since 1995 and shows a slight improvement compared to the previous year. The cod condition in 2002 is similar to that observed in the middle of the 1980s.

Discussion

Is there regular information available on cod winter condition from 1994 until now?

Answer: No, not since Gadus' winter missions were discontinued.

Do the data on condition come from fish from all age categories?

Answer: The data on condition come from specimens from 30 to 55 cm in length.

2.2.1.4 Maturity Ogives (Johanne Gauthier)

Data on the new maturity ogive produced for 2002 and the matrices of average lengths at age proposed to estimate the reproductive biomass were reviewed. An update on the various ogives used over the years was also presented.

The new maturity ogive for 2002 is based on samples collected during mobile gear sentinel fisheries survey carried out between April 30 and May 19, 2002, mainly in subdivisions 4Rc and 4Rd, but also in 3Pn.

The maturity ogive is developed from a logistic curve allowing us to calculate the proportion of mature females to the length. Thereafter, the average length at age is used to transfer to proportions of mature individuals at age rather than to the length. Contrary to former years, it is proposed for this year to carry out this transformation from the matrix of average lengths at age from data of scientific surveys (sentinel fisheries and DFO surveys) rather than with the matrix from commercial fisheries data. This approach is more rigorous as it makes it possible to eliminate the problem of over-estimating the average length at age for the small age groups (3, 4 years), which can affect the commercial samples and which is mainly related to the limit of the commercial size (42 cm) and to the selectivity of commercial gears.

The main conclusions to be retained in connection with the maturity ogives were as follows:

- The length at 50 % of maturity dropped down from 1990 to 1995, then went up from 1996 to reach, in 2002, a value similar to that observed in the middle of the 1980s.
- The new ogives used do not affect trends for biomass, but the values in absolute terms are decreased.

Discussion

With the method used, variable length distributions around selected average were not considered. Someone asked if the lengths at age used (surveys) are representative of the stock.

New recommended analysis:

To ensure the conformity of the values used with the population real distribution lengths, it was proposed to use the age/length keys available for the conversion of maturities at length to maturities at age.

It was also proposed to try conversions from the longline lengths at age.

2.2.1.5 Tagging Program (Louis Pageau)

This program was initiated to study cod migration and to bring new knowledge on stock mixing. The initial program began in 1995, and the high reward tagging program ($100 per tag) was implemented in 2000. Until now, more than 57,000 cods were tagged as part of these two programs, and approximately 2600 tag returns were listed.

The main conclusions of this survey were as follows:

- The first results of this tagging program confirm mixing between cod stocks. This would be particularly significant with division 3Ps and would not only relate to subdivisions 3Psa and 3Psd, but also to division 3Ps globally, as evidenced by recaptures up to the Bay of Placentia.

- Tag return rates are higher for high reward program than for the initial program.

- Based on double taggings (two tags per fish), the tag loss rate seems to be acceptable (approximately 25%).

- The low tag return rates observed for the initial program (1995-1999) can be related to several factors such as deficient training of taggers, non-compliance to existing protocols, high death rates due to improper tagging conditions (e.g., excessive gear soaking time), inadequate diffusion of information about program and, finally, improper reward program.

- Calculation of exploitation rate based on tagging data is biased as the actual rate of return is unknown and as mortality rates related to tagging are unclear.

- Data resulting from this program could be improved by different ways. These include shifting from a lottery to a $10 reward per 2002 tag returned. Other improvements could be made to the program: enhance training, tighten tagging activities follow-up, use more frequently hand lines and feather hooks to decrease tagging-related mortality, etc.

Discussion

An industry representative asked how high catch rates of commercial fisheries could be matched with such a low rate of return?

Answer: The above-mentioned factors that limit the rates of tag return give a good explanation of the situation. Moreover, it must be consider that the tagging effort is aimed at the smallest cods. Since they are not fully recruited to the fisheries, it is normal that the rate of exploitation based on tagging appears to be lower than that of the commercial fishery.

2.2.1.6 Indexes of Abundance (Alain Fréchet)

The indexes of abundance that will be used in the Sequential Population Analysis (SPA) are reviewed — the two indexes derived from fixed gear sentinel fisheries (gillnets and longline), the two indexes from mobile gear sentinel fisheries (July and October) and the Needler index. The highlights from this review are as follows:

- The gillnet index indicates a slight rise from 2001 to 2002, but the trend since 1995 is rather stable or slightly downward.
- The longline index showed an upward trend from 1997 to 2001, but a significant decrease in 2002.
- The Needler index shows a downward trend since 2000 and reached a level approaching that of the period when the moratorium was established.
- Missing strata of the Needler survey were derived using the multiplicative model, and the trend analysis of this index with or without the use of this technique shows nearly identical trends.
- The mobile gear sentinel fishery indexes both indicate a drop from 2001 to 2002.

Discussion

Is the Gadus' winter mission index used in this evaluation?

Answer: No, we stopped using this index a few years ago when we realized that cod distribution had changed and that the Gadus sampled a less and less representative proportion of the stock.

It was mentioned that it would be important to see variation coefficients linked to the results of the multiplicative model used to derive the Needler survey missing strata.

A participant indicated that he did not believe in the biomass estimate calculated from the Needler survey. This index would have continuously underestimated the biomass, and this phenomenon would have been increased in 2002 by problems with URI trawl and by a cod distribution closer to the shore, to depths lower than those covered by the survey (less than 20 fathoms).

Answer: It is more important to verify the index trend and the manner it is used in the SPA than focusing on its absolute value. The Needler index trend for cod is similar to that of mobile gear sentinel fisheries. Moreover, the index for fixed gears sentinel fisheries (longline), which covers the upper depths (less than 20 fathoms), also indicates a downward trend. Finally, hauls missed due to gear failure occur in all missions, and particularly in the case of the Needler as she often travels over very irregular bottoms and uses a shrimp trawl, which is known as a more fragile gear than standard bottom trawls. However, the participants agreed on the importance to make sure that gear problems in 2002 had not been of a magnitude that could affect the validity of this index for this particular year. This question will be discussed in more detail later during the review.

Recommended actions:

- To examine other species catches for the 2002 Needler survey in order to make comparisons with the situation for cod.
- To examine statistics concerning gear failures in each division surveyed by the Needler in order to determine if the 2002 is actually a problem.
- To present biomass proportions for each depth stratum in order to see whether the survey could indicate a possible change in cod distribution.
- On the longer term, it is suggested to perform analyses only with 4R data in order to detect changes in cod distribution towards this division. This point could perhaps explain the fact that stock is declining while showing more positive signs in 4R.

2.2.1.7 Industry Presentations (Jason Spingle and Guy Perry)

A total of five documents were presented by industry representatives. These documents related to the following subjects:

☐ Estimation of the exploitation rate based on a tagging experiment carried out in 3Pn-4RS from 1998 to 2002 – Jason Spingle;
☐ Cod migration patterns based on a short term tagging experiment carried out in 4Rd and 3Pn in October 2002 – Jason Spingle;
☐ Results of telephone surveys made in 2002 with cod fishermen using fixed gears – Jason Spingle;
☐ Review of fishing effort and catch rate distributions in 3Pn4RS for the period from October 21 to 27, 2002 – Jason Spingle;
☐ Review of cod landings made by fishermen using fixed gears in 3Pn4RS and from the dockside sampling program – Guy Perry.

The highlights for the first study were as follows:

- The work protocol was based on studies made by the DFO in 3Ps in October 2002. It only involved fixed gears and comprised a step where fishermen were contacted in order to verify if tagged cods were captured and the proportion of tag returns. The goal of this verification was to adjust the rates of return so they are more close to reality.
- The rates of exploitation for 2002 are very variable (from 0.93% to 25.5%, average per subzone). However, industry representatives considered them lower than those established from the SPA.

Discussion

What could explain the fact that rates of return calculated based on returned tags (telephone surveys) are definitely higher than those established with a high reward tagging program involving a $100 reward per tag?

Answer: While no explanation was given on this matter, it was mentioned that the participants could not see the details of calculations resulting in these exploitation rates and that it would have been desirable to do so.

In such a study, it is important to keep in mind that the exploitation rates must be associated with the area where the catch occurred, and not with the area where tagging took place. It was mentioned that several particular assumptions must be met (without naming them) in order to calculate the exploitation rates based on tagging data, and that it was not possible to verify that these assumptions were respected in this study. Moreover, it was recognized that this kind of study generally underestimates fishing mortality.

According to their length, tagged cod seemed to be 5 years old for the most part. It was mentioned that the exploitation rate established by the SPA for these cod is of 0.03, which would indicate that the rates calculated with the SPA are not excessively high compared to the rates derived from the tagging study.

The highlights of the second study were as follows:

- During this experiment, nearly 1300 cod were tagged in four different sectors of divisions 3Pn or 4R (Codroy, Port-aux-Basques, Burnt Island and Rose Blanche).
- Only 50 recaptures occurred in the days or weeks following tagging. According to industry representatives, such a low rate of short-term return in these sectors during significant commercial fishing activities could be considered as an indication of a low rate of exploitation.

The highlights of the other studies tabled were as follows:

- The information collected from the fishermen (telephone surveys) would indicate that the length and condition of cod captured in 2002 was similar or greater than those observed in 2001. Moreover, fishermen catch rates seem to be stable in 4RS and upward in 3Pn.
- Average landings recorded in various sites of divisions 3Pn and 4RS in July 2002 and during the period from October 21 to 27, 2002 are considered as excellent by industry representatives.

Recommended actions:

The analysis of information collected with telephone surveys should make it possible to differentiate commercial fishermen from sentinel fishermen so that it would be possible to compare the information reported by sentinel fishermen with their actual catches.

Presentation of survey biomasses by depth stratum.

Biomasses for the 20 to 50 fathoms depth stratum showed the same trends for the surveys (Needler and mobile gear sentinel fisheries of July) and were consistent with the information given by fishermen, that is to say that catch rates would be better in the shallow depth strata.

ADAPT formulation:

More details on the formulation were requested, in particular for the calculation of Fs for higher ages (i.e. F 7 to 9 years).

2.2.1.8 Sensitivity Tests of SPA for 3Pn4RS (Noel Cadigan)

Four alternative runs were carried out. The runs differed in weighting of indices, variations in F and M. The tests concluded that the SPA is robust to the data and assumptions. Further attempts to refine the model or data would not substantially change the results or conclusions.

Discussion

What is considered as strong perturbation of M, for example a change towards 0.6? It depends on the year where such a disturbance occurs, but would be in the order of 14 units.

Residuals of the Needler survey: the 4 last years show a pattern. What is the scale? The longline trends are evident in the residuals. Longline trends are inconsistent with the othe surveys.

What is the impact of applying the F of ages 7-9 to the oldest ages? Should use ages closer to the oldest age to estimate F.

To run ADAPT with only one index would be interesting. That was done. The most optimistic result is with the longline index, and the less optimistic was that with the gillnets.

Estimates for higher ages seem to show a retrospective pattern. Estimations for these ages seem poor. A suggestion was made to consider the 4 oldest ages, not to fix them. If so, it would be necessary to recalculate indexes one by one.

The 2002 Needler survey residual pattern is high. What is the reason for the low catch rates? The Needler 2002 survey point has a low effect.

Why are higher ages (10-13 years) estimated by the model? We already examined this issue, and we concluded that there was useful information to preserve.

An update was made on additional analyses to perform.

- To re-examine maturities at age using the age-length key.
- To use lengths from longlines to convert maturities at length for maturities at age.
- To check trawl failures during the 2002 Needler survey.
- To estimate the dome and re-enter indexes one by one in ADAPT. This does not mean that we must reject any index.
- To remove the 2002 Needler survey from ADAPT formulation.
- To review retrospective patterns of ages 7-9 that are used to estimate age 13.

It was pointed out that it would be necessary to examine the effect of discarding and ghost fishing. The effect of inflating the net catches in the series could also be examined. It would be preferable to inflate the catches only for the years where discarding supposedly started. According to the industry, 1999 was the year of the implementation of the grading system in 4R. The value of 20% seems realistic for this exercise.

A participant noted that M=0.4 already includes undeclared catches. The chairman estimated that that it would be useful to produce such scenarios to examine whether this could change our perception of the state of the stock. A participant agreed with this position, while another argued that this situation did not start in 1999 and that he did not really understand the usefulness of such a scenario.

2.2.2 Addendum discussion

Rapporteur: Daniel Duplisea

***Points of clarification*:**

Feeding data throughout the 90s are dominated by Needler survey but has Sentinel data as well.

Maturity is determined from length-at-age on the survey. The July Sentinel is then used to make an age-length key. Therefore by combining these things we get the age-based ogive.

2.2.2.1 Presentation on Tagging Experiment Exploitation Rates Update (Jason Spingle)

Clarification points:
Short-term tagging experiments were included with other tagging data.
A straight averaging is done over all explortation.
It is advisable to weight the averaging of overall expt rate by the size of each experiment.
Should also not include tagging experiments that were halfway through the year.

Action:

1. should exclude tagging experiments during year 0
2. do not estimate exploitation rate for a year from experiments that were done after fishing season in that year
3. make a weighted averaging of experiments according to the number of tags in that experiment

2.2.2.2 Discussion of Alain Frechet's paper:

Maturities:
New maturities from the RV survey should be used. These are based on May survey data.

Smoothing of data in blocks is probably the best way to go in future because annual changes are reflecting a lot of the noise in the length at age. A cohort maturation model may be a better way to calculate maturity o-gives as it actually follows how a cohort matures rather than giving year estimates over many cohorts.

Tear-ups in 2002:
8 tear-ups not in prime cod territory. Tear-up defined as unuseable tows (there is a 1-5 scale, codes 3,4,5 mean that the tows need to be redone).

Jason feels that net1 was not fishing well at the beginning of the survey yet it was also used to fish the end of the survey.

Some areas were avoided in order to get 3 tows per stratum and these are often done in areas where Jason feels there are no cod.

Scanmar was not working on the first half of the survey because the batteries were dead so we cannot know from scanmar if the gear was fishing properly.

Action:
Because of the doubts associated with the 2002 survey year, we are going to have examine the results of the ADAPTt runs to examine the impacts of this year. We are not ignoring the issue.

ADAPT runs:

Numbers of large fish have gone up but not considerably. Gillnet run 20% increase and the Needler 2002 runs are considered sensitivity runs while the former is considered standard. All the new runs have the age13 estimates.

Ages 7-9 were used to estimate F on the age 13 fish. It is probably better to use the F on the oldest two ages (11 and 12) to estimate the F on age 13. This should smooth out the results and prevent the decrease in F.

Final run:

Average F on 11 and 12 for age 13
New maturities

Sensitivity runs:

Gill nets with discards
No 2002 needler

Tagging exploitation rates:

Initial tagging mortality of 1.3 may be higher than currently used.

4R and 3Pn have a vastly different reporting rate and in future should use regional reporting rates in weighting.

Perhaps refine experiment to include winter and summer which will roughly correspond to the fishing season being on or off.

The tagging database is not yet validated and therefore considers it tentative.

2.2.2.3 Conclusions

The main conclusions were as follows:

The abundance and spawning stock biomass remain low. The stock abundance increased between 1994 and 1999 but has declined since. All three abundance indices based on research and sentinel trawl surveys increased from 1995 to 2000 but have declined since. The index from sentinel longlines increased from 1995 to 2001 but declined in 2002. This decline is most pronounced in southern 4R. The gillnet index appears to be stable.

The recruitment estimates at age 3 have been declining since 1998 and are predicted to reach a historic low in 2003. Energetic condition and growth have improved in recent years and fish now mature at older ages. Natural mortality of adult cod remains high in this stock. Seal predation is a major factor contributing to this elevated mortality.

Cod are increasingly concentrated inshore in 4R and thus are more available to inshore fisheries. A portion of the stock may be becoming less available to research vessel and sentinel trawl surveys but is monitored adequately by sentinel longlines.
Exploitation rate has been high since 1999. Unaccounted fishing mortalities may have increased in recent years due to under-reporting in the recreational fishery and gillnet discards in the commercial fishery.

With no fishing, the stock is expected to increase marginally in 2003. With a 1,500 t fishery, stock abundance will likely not change. Catches of 7,000 t (the TAC since 2000) is estimated to result in a decline of about 12% of the spawning stock biomass. In 2002-2003, the TAC was 7,000 t. and as of December 31, 2002, 6,246 t were landed.

Spawning stock biomass is estimated to be below the conservation limit reference points for this stock. There is a high likelihood that the productivity of stocks below the conservation limits has suffered serious harm.

2.3 Southern Gulf Cod - 4TVn

The assessment was based on information from annual research vessel surveys, landings data, commercial catch at age, sentinel survey data, otter trawl catch data and the annual telephone survey to collect industry views.

2.3.1 Assessment and Discussion

Natural mortality is estimated to be around 0.4 currently. In the 1960's, it was around 0.1-0.2. In the 1990's, indications are that it was much higher.

Age composition: effect of mesh change size in early 1980's visible (less small fish)

Growth: weights at age – fish were growing much faster in the 1970's than now. Weight at age declined in the 1980's and reached a minimum then. From 1990-1995, there was an increase. Weight at age declined in 2002 in comparison to 2001. Size-selective fishing considered to be a factor. Other factors could be density and temperature (small effect but some effect).

RV Survey: survey done in September. In 2002, there were two large sets, less than 6 nautical miles apart, which caught 12t of fish and represent half of the survey. These have an influence on the survey trends. All information indicates they were valid sets. However, in terms of the assessment, we had a look at the impact of keeping them in. In 2001, a large set consisted of juveniles and in 2002 the large sets were of fish in the 35-50 cm size range.

After closure, older ages were seen in the survey. In 2002, more fish at age were observed than in previous four years and this is considered to be a year effect. The survey is quite consistent in tracking year classes.

Distribution: Currently, a larger proportion of the stock is found in the eastern part of the range than during the 1970's. Reasons for this shift are unclear but are being followed up. This could be an indication that the migration is starting earlier or sub-populations are being exploited at different levels.

Condition: In 2002, condition was good and within the range of good condition that has been observed lately.

Sentinel Surveys: With the exception of trawl catches, all Sentinel Survey gear (longline, gillnet, and lined trawl) are either down or stable in relation to last year. For many of these, the year effect is not significant and there is no trend in catch rates for the gear types. Comparison of indices reveals fairly similar trends for all of them and all fairly flat for recent years.

Relative F calculations are derived from commercial catch at age vs RV catch at age. Dramatic increase in the late eighties was followed by very small values during the moratorium. Relative F has increased after 1998 with the resumption of fishing.

Total mortality (Z) has been about 0.4 since 1996. If the two large sets in 2002 are excluded, the Z increases.

Natural mortality (M): There is no indication of a decline in natural mortality.
Estimations of total mortality (Z) do not suggest a decline in M. Another way to test this is to estimate M within ADAPT. This was tested by estimating M for time blocks, starting at 5 year intervals and increasing to 9 years. It was noted that M was fixed at 0.2 for the first time block. Three different synthetic populations were generated and ADAPT was applied to these. Five hundred simulations were done and the M profile was recovered, though the M generated and estimated M's could be quite different. It was concluded that M does not appear to have declined significantly in the recent past.

ADAPT: The same formulation from last year was used this year. Two calibrations were done, with and without the big sets. Some observations on the results:

- Residuals – excluding the big sets resulted in positive residuals for 2002.
- Correlation – no large values noted
- Bias – small
- With or without the big sets, the calibrations were relatively similar. There was no reason to reject these two sets. An analysis excluding the two sets found that the impact was about 10%. Estimates of SSB including the two sets were about 72000t and 65000t if they are excluded. Exploitation rates very as well from 8 – 10%.

A comparison of biomass between 1993 and 2003 indicates that there are older fish in 2003 but less biomass is composed of younger ages (3-6), about half of 1993 values. This indicates that things will get worse before they get better.

Recruitment: since 1948 averages about 1 million fish. In the 1970's and 80's, recruitment went up to 2 million or more. Survival was correlated with pelagic biomass of herring and mackerel. The current mackerel population is the highest on record and herring is doing well. As a result, 1999 recruitment is the lowest on record, 1998 is the third lowest and the 2000 year class is around the same level as well.

A question was raised concerning the weighting of the indices. No weighting is applied to the indices so equal weighting is implied. It was further asked whether the VPA was tuned with the RV series only. Tuning with just the RV series gave similar results as the full indices tuning. It was observed that the RV series probably gets a relatively large weight due to the length of the time series and the number of age groups. In response to tuning with day and night sets as separate series, it was observed that the VPA does not converge due to breaks in the time series.

With uncertainties in recent years, it was questioned why a zero tow would be an anomaly. Zero tows are always present in the RV samples, the anomalies are the two large sets.

Biomass at age is the largest that has been seen in recent years but recruitment is low in absolute terms. However, in terms of survival, it is not anomalously low.

The relationship of recruitment to pelagic biomass was questioned with the observation that some herring stocks are not large. The biomass of fall spawning herring is in good shape and nowhere near the low levels of the seventies. Spring spawning herring are at low abundance. Mackerel stocks are strong now.

2.3.2 Addendum Discussion

Rapporteur's notes - SGSL reruns.

Need an independent measure of year-class strength – egg surveys, acoustics, tagging. Accept the conversion factors as they stand – there may, however, have been some 'drift' in the catchability of the Needler since the comparative survey.

Discussion:

Cod egg surveys don't always work – in the Irish sea, for example; there was an identification of egg problem. The issue of stock biomass estimation from egg surveys is a complicated and difficult one. Egg production is a desirable thing to know, in any case.

Acoustic surveys in the overwintering area(s) are a possibility for biomass estimates.

Length compositions - mesh sizes changes weren't taken into account? No, these are just an indication of the size ranges brought to port. Estimates of discards also not included.

Needler works better in shoal water – in the last few years of the redfish fishery, the Needler survey showed lots of redfish when they were declining in the population.

Question of whether the 4T stock is one unit, or is composed of separate spawning components – there is no way we can, at this time, identify separate spawning components – trace elements, etc. As well, the fishery exploits all components as they enter and leave the Gulf; management of that as separate components would be a challenge. If the PEI component is the only one left, we would be in trouble.

Estimates of year class strength from the 80s from the SPA is higher than from the GLM; the RV survey on its own gives less 'anomalous' year class strengths around 1980. The difference in the graphs may also be caused by the difference in using the survey series as 3 instead of as 1.

It was suggested to go with the original analysis with the 2 large sets.
Assessment was accepted – go to the SSR and projection for 1 year, Armstrong and risk plots.

Long-term projections – scientists are uncomfortable with these, too many assumptions. A 5-year projection; the minimum approach is to use the deterministic approach. A 5-yr projection is problematic with assumptions for recruitment. Let's make reasonable assumptions. It was noted that the projections should be as consistent as possible across stocks. It was requested that an indication of our discomfort with 5 year projections be included in the proceedings of this meeting.

For the projections - start with beginning of year 2003 numbers, average weights, recent exploitation pattern recent average r/ssb for recruitment (use last 10 years for average), bootstrap with ADAPT.

A participant suggested using more recent than the last 10 years, for estimates of weights, maturities, and recruitment. Maybe last 3 years for weights at age. Treat all these cod stocks the same (generally):

Choose 3 years for maturities, weights at age, pr (2000 to 2002). For r/ssb, drop most recent 1 year, then use 5 years for average.

For 5-year projections, use 2 options: 1) no fishing; 2) status quo F: average recent F (since 1999).

2.3.3 Conclusions

The main conclusions were as follows:

- The probability of being below the limit reference point is 100%. Last year's projection with the current TAC was 72000t and this year the estimate has dropped to 70000t.

- M remains high. Even with no fishing, given the low recruitment, the SSB is expected to decline over the next 2 to three years. Rebuilding in the short term is unlikely. Biomass is near the lowest level observed and is slowly declining. Recruitment has been below average for the last decade and the 1998 to 2000 year classes are amongst the lowest in record.

2.4 Eastern Scotian Shelf Cod - 4VsW

This assessment is based on three indices of abundance: the research vessel surveys conducted in July and March and the fall Sentinel Survey.

The stock has been under moratorium since 1993 and removals from bycatch and surveys have been less than 300 t per year since 1998. Since the moratorium, the spawning stock biomass has declined steadily in the absence of a fishery and is at or near its all-time low.

2.4.1 Assessment

Premoratorium catch averaged 50000 t (1958-1992). Age distribution has been truncated and fish are much smaller in the catch since the early eighties.

Seal consumption – recent work on fatty acid composition suggests seals eat much less cod than previously thought.

Distribution – in early years, distribution covered the shelf and cod were everywhere on the offshore banks. In early nineties, more patches observed. Now, patchiness and low numbers characterize the distribution. The stock is occupying much less of the available area than it used to. Distribution did not collapse in the seventies when the stock declined.

Sentinel – only in the nineties and recent years. A key observation is that the Sentinel covers inshore areas that were not covered in the survey – accounts for 70% of the biomass in some years. This is a fall phenomena however and does not affect the July survey in a major way.

Size – mean length shows a downward trend since the eighties. Condition factor (Fulton's K) increasing in 4V but not 4S. Mean weight is lower than average for age 3 and older but not for age 2 which is average. Maturity also occurs at smaller size in recent years.

Recruits, SSB – proportion of first time spawners high in SSB, 85% from the partially mature 3 and 4 year old cod in 2002. Abundance of older cod continues to decline. The 1999 yearclass seems substantial. Since the closure of the fishery, there has been an average negative production in this stock resulting in an erosion of SSB.

Mortality – Survey Z from q-corrected RV population numbers indicates an increasing trend in total mortality even after moratorium.

2.4.2 Discussion

A participant inquired about a previously used constrained variable predation model and was informed that this was no longer used.

A question was raised about q-corrected RV numbers. Why not use ADAPT q's rather than meta-analysis. Each assessment that goes into the meta-analysis, how does the survey overlap with the stock, is each stock/survey overlap unique? The meta-analysis cannot account for that, so has reservations about the meta-analysis q-corrected estimates. The response was that the q at length is kept constant in the analysis as length remains constantly catchable. Also they have compared q's with ADAPT and the answers vary little. The signal is so clear in the survey that it makes little difference.

It was noted that the FMF model historic trajectory was very different and that the choice of model needed to be narrowed down in order to estimate reference points. Reference points were derived from the last assessment but can compare reference points from various approaches and reconstructions.

A question was posed about seal related mortality resulting from a parasite rather than direct predation. The response was that this issue was looked at and parasitism was not at a critical level. Another seal related question was competition for food (sandlance) but there was no indication that prey species were limiting in 4VsW.

A participant asked how cod were faring on the other side of the Atlantic. It was noted that there are some interesting parallels but the main message from the other side is there are too many fishing boats. Exception would be the Baltic where there are important environmental aspects.

A participant was surprised about the inshore observations, noted that the RV surveys have no points inside 50 fathoms. The response was that the survey was restricted to below 50 fathoms. The inshore was a concern that they were being missed in the July survey but looking at the fishery and discussions with fishers it was found that the inshore aggregations are a fall phenomenon. Presumably the fish move inshore to spawn but the important point is that they are not inshore in the summer.

2.4.3 Conclusions

The main conclusions were as follows:

- There are no indications that stock recovery is imminent.
- Natural mortality on both adults and juveniles is extremely high. Recruitment has been very low for more than a decade. The 1999 year-class appears to be the largest since 1990 but is still substantially below the overall mean. The size at age in the stock has been small but stable providing little growth production. The fish condition has improved in the last two years although it has not translated into improved growth.

Spawning stock biomass is estimated to be below the conservation limit reference points for this stock. There is a high likelihood that the productivity of stocks below the conservation limits has suffered serious harm.

3.0 Reasons for Lack of Recovery

The meeting considered a list of over 40 grouped hypotheses for the failure of the cod stocks to recover since the moratorium (see Annex 4). This section reflects the grouping of hypotheses and the discussion concerning the strength of the evidence to support the hypothesis as a causal factor in the failure to recover. This section also attempts to capture the range of speculation and discussion around the hypotheses; the conclusions are summarized and reported in Section 6.

Rapportuers: Paul Fanning, Corey Morris, Daniel Duplisea, Doug Swain

3.1 Inadequate Recruitment

3.1.1 Spawning stock

H1: The spawning biomass is very low. There is a stock-recruit (S-R) relationship, and the stock is down on the ascending limb.

Absolute number of recruits is very low in all cases. The S-R points are all clustered near the origin with both low recruitment and low SSB. Any changes in this will require extended periods of time.

2J3KL has a distinction between inshore and offshore components i.e. offshore and overall are very depressed but there is no information to say where inshore stocks are relative to historical values.

H47: Patterns of distribution of spawning components in space and time have changed

4TVn - Changes in distribution in 4T is seen in the feeding distribution. It is not clear, in the last 30 years, that there has been a change in the spawning distribution. There is little evidence for or against changes spawning distribution.

2J3KL - Northern cod has much reduced densities in many spawning areas although it is not possible to say there is no spawning there. There is no evidence that there are any large aggregations in the historical offshore areas.

3Pn4RS - Northern Gulf has indirect evidence of loss of the 4S spawning component. This used to be 25% of fishery and now virtually none. Well documented spawning aggregation off Baie St Georges etc suggests that spawning in west has severely declined, although more eastern aggregations appear to be consistent.

4VsW - Eastern Scotian Shelf has seen major changes in spawning components, especially loss of Sable Island spring spawners, also Middle Ground in 1980's. No guarantee that rebuilding a significant biomass will restore the spawning component structure (meta-populations).

Recruitment Rate R/SSB – If recruitment is low in an absolute sense, has the recruitment rate (recruits per spawner) declined?

4VsW - Eastern Scotian Shelf shows well below average R/SSB until most recent yearclasses. This may be a spatially local effect.

Other stocks do not seem to be especially low and in some cases were quite high at times in the 1990's. If density dependence was a factor we would expect to see particularly good R/SSB, which we are not generally seeing.

It was observed that the historic recruitment productivity should have supported a rapid rebuilding with the closures and restricted fisheries that were in place. The current situations clearly did not rebuild. Expectation of swift recovery was affected by unusually high R/SSB in the 1970's. The question is whether there is a density dependent relationship in R/SSB?

3.1.2 Early Life Stages

H8: Physical Oceanography – Changes to salinity, temperature, stratification are less favourable than they used to be.

High interannual variability is observed in oceanography as well as primary and secondary production. There have not been extended periods of consistently unfavourable conditions across the Atlantic zone. Since mid-1990's conditions have been reasonably good for cod Early Life Stages, as well as other species.

4TVn - Suggests that some factors are not currently favourable (since 1999).

3Pn4RS - Strong changes have occurred in the Northern Gulf of St. Lawrence, although the effects are not known.

2J3KL - has had a period of very cold years although the most recent years appear to be better. No clear view on the size of the most recent yearclasses.

It is not clear what factors are the important ones for Early Life Stages (e.g. small scale movement). Big changes are occurring in the arctic and more freshwater is being included in the Labrador current. Species are changing their distribution as a result and more changes will happen further south as this continues. Past conditions may not be a good guide to the future.

H9: Transport paths have changed such that eggs and larvae travel through or end up in areas less suitable for development.

In all stocks there are changes in either egg or larval movements due to simple variation in the water flows. High resolution flow models exist for various areas. These could be used to model egg/larval movement from assumed spawning grounds.

H10: Oxygen content of the water has become lower, increasing mortality.

Not an issue for Early Life Stages

H11: Increased predation on Early Life Stages (which predators would be important?)

Only Southern Gulf of St. Lawrence has a specific analysis where pelagic planktivores have been implicated. Shrimp seem unlikely although other zooplankton predators may be important.

H14: Competition for Early Life Stages food (competitors have increased abundance or consumption, reducing food supply for cod)

No data in most cases and for pelagic fish it would be indistinguishable from direct predation on cod eggs and larvae.

3.1.3 Reproductive Biology

H2: small/young spawners less effective (less fecundity or viability of reproductive products) and age/size composition of the SSB is young/small.

Effect has been observed in all stocks but in 4T the age of maturity has increased but size has declined. In 4T there was no relationship between mean size of spawners and R/SSB.

Effect of size on egg production is stronger in Iceland or Barents Sea than in NW Atlantic. In all areas the power is greater than 3 (greater than isometric) and may be close to 4 in Northern Gulf of St. Lawrence (refers to the exponent in the equation relating size/weight to egg production). Reduction in fecundity due to first time spawners is important in at least Eastern Scotian Shelf.

H3: Spawner condition is reduced resulting in impaired fecundity (per kg or per capita)

Trends have differed between areas but in some areas it has been low or very low (critical). Spawning of low condition fish can be deferred, reduced or may cause mortality. Spawner condition in the mid-90's was bad in most areas but there has been some recovery in some stocks since 1999. There are mixed signals between stocks. There is a need to pick an appropriate period to monitor condition as seasonal changes are important. Also the mean condition may be relatively unchanged but the poorest condition fish may be worse and in larger proportion.

H4: Allee effects (Abundance of spawners is so low that spawning behaviour is disrupted, disproportionately reducing fecundity).

Frank and Brickman showed that the presence of multiple spawning groups could mask a depensatory S-R relationship. This is a separate effect from predator pit depensation. Also see Shelton ref. Detection of depensation has been shown to be very difficult. Conditions for it to exist and be undetected exist in all these stocks.

H7: The effect of human activities that could disrupt spawning behaviour.

We refer to these types of disruption as human as opposed to trawling to account for things such as seismic surveying. Over the past decade there has been a large decrease in trawling activity while the amount of seismic surveying has increased.

What is the role of seismic testing on spawning cod?
The data available does not suggest an effect on the early life history of cod on the Scotian shelf. There also does not appear to be an effect on the older fish. However there was much less seismic testing in the past as compared to what is proposed today,

and there is little evidence to suggest it will have an effect. To address this issue in more detail, there will be a meeting to discuss the effect of seismic surveys on cod.

For the 2J3LKL area in recent years, there is little fishing before mid July. In Smith Sound where the last large biomass of cod over-winter, the number of seals have increased. Seals in this area during the spring spawning period, April and May, could affect the spawning behaviour of these cod. For example, this past year George Rose observed a different cod distribution in Smith Sound. This year unlike other years cod were concentrated towards the bottom. In past years fish have been higher in the water column, or spread throughout the water column. It was also noted that more seals were in the area. When seals are in the area of prey, the prey behaves differently. Prey responses include moving deeper in the water column, possibly moving away from predators. There is therefore potential for predators such as seals to disrupt behaviour.

3Pn4RS and 4TVn - Northern Gulf and Southern Gulf.

Seals are around before and during the spawning period. There is overlap in space and time, but there is little evidence of an effect. For the Northern Gulf there is not much overlap for harp seals during the spawning time. Harp seals leave the gulf in spring when cod are spawning. There is overlap however before spawning, during the winter. In spring, Grey seals are exceptionally plentiful. Grey seal numbers have gone up a lot compared to the 1990s, and the effect of Grey seals could have a larger effect than harps that have already left the area.

For the gulf region crab fishing does not generally overlap with the spawning of cod.

Based on the data available, it seems the direct effect of fishing on the spawning activity is not a major problem.

H44: Life history of cod has changed (due to directional selection by fishing?) such that energy allocation between reproduction and growth is different.

Somewhat specific to the Southern Gulf. The age of maturation has changed over time and there is direct evidence of size selective effects of fishing, in the Southern Gulf stock. The allocation of energy to reproduction at an earlier age and size would suggest that these fish cannot produce as many eggs as larger fish, and fish in poor condition are less likely to produce as high quality eggs.

The smaller size at maturity compared to historical data is a common phenomenon among all stocks being discussed.

3.1.4 Spawning Components

H5: Individual spawning components have been greatly reduced within the population, with detrimental impacts on stock productivity.

There is suggestion that reductions, if not complete removals, of spawning components is a potential problem. However we do not know the total effect. What is available in the literature suggests we should be concerned. Only after an increase in the biomass will the effect of lost spawning components become clear. In addition, spawning is occurring in areas today where it did not occur in the past.

2J3KL - For the 2J3KL, we are not really sure if there were independent spawning components or not. There may have been a contraction in spawning areas, where there was once spawning all across the shelf and banks. There is no information to suggest a shift from old to new spawning areas either. The evidence is more indicative of a redistribution or contraction.

3Pn4RS - For Northern Gulf some spawning aggregations, and changes in spawning have been identified. In the 1980s cod would move further along the estuary and this may have had effects on spawning. Today this distribution is more restricted than in 1960-1970, when cod moved further along the north shore during the spawning period.

There seems to be some changes in the location of spawning for age 6 fish. For example, if an entire spawning component of cod moves from one location to another we can expect changes. For example, if cod do not spawn in the Anticosti gyre, this can have an effect on the distribution of eggs and larvae.

3.2 Growth and Production have been inadequate

3.2.1 Adult Growth

H44: Life history of cod has changed (due to directional selection by fishing?) such that energy allocation between reproduction and growth is different.

4TVn - Life history characteristics of adult cod, at least for some areas such as the Southern Gulf, may have been affected and changed by selection.
Southern Gulf cod size at age was declining in the late 1970s and early 1980s and remains low compared to the period before 1975. For the Southern Gulf, low weight at age is important in the lack of increase in spawning stock biomass.

3Pn4RS - For the Northern Gulf cod, the length at age declined in early 1990s but increased during the late 1990s and declined again during the last couple of years and are at average currently.

2J3KL - lengths at age vary spatially, and are variable within areas also. Cod in 2J are growing slower and cod in 3L staying the same. Little change was observed in the mid 1990s. It is difficult to consider age 7 fish in 2J3KL, like is done for other areas, because there are no age 7 fish available in the offshore. However, growth is temperature dependant and the model fit is consistent with observations elsewhere.

Trophic limitations – Energy supply to cod is limited by changes in food abundance (key prey species) and/or food quality (energy density of prey).

Is the energy supply to cod a factor to consider for non-recovery?
Abundance and distribution of prey
2J3KL - insufficient capelin for 2J3KL cod may play a role in the lack of recovery. Capelin abundance is down considerably. In addition, the presence of capelin in the

stomachs of cod is reduced. Capelin prevalence is down in the diet of 2J3KL cod, and capelin abundance is also at low levels.

4TVn - Southern Gulf. There does not appear to be an effect of low capelin abundance, or low abundance of other forage fish. There appears to be increased food availability such as herring and mackerel, and where these increases have occurred they appear to be utilized by cod. Capelin density is lower in the gulf but their distribution has expanded considerably. There appears to be as well a shift of the centre of biomass to the south. They are much more common in the southern Gulf than before. The S. Gulf also seems to show increases in capelin throughout the 90s.

3Pn4RS - Northern Gulf. For the Northern Gulf and the entire Gulf in general, the spatial distribution of capelin has increased. The distribution of capelin has shifted southward, and has increased in abundance in the south. Northern Gulf capelin has been important in some years, but shrimp are also important.
Capelin is not the only food source in the N Gulf, shrimp is also important. They eat 80 other things in the N Gulf. The first 2 years of the Needler survey showed that cod were eating a lot more capelin than in subsequent years.

4VsW - Eastern Scotian Shelf, there has been no change in the prey availability. There are a variety of prey types other than capelin, which appear important in the diet. Increases in the abundance of prey such as herring is also consistent with contents in stomachs. Prey abundance has not decreased, in fact it has increased but this does not seem to be affecting condition.

Temporal availability

For the Southern Gulf, the shortened feeding season has contributed to the small size at age, and poor growth. This is important for the Northern Gulf as well. For the Northern Gulf there has been a change in the duration of the feeding period and winter condition of fish. This may be affected by the fall feeding period. Capelin increased in 1990 related to 70s and 80s. This is a positive point perhaps for the northern and Northern Gulf. Winter condition of cod is not good. In recent years the peak condition in the N Gulf occurred in late August while in earlier years it occurred in the late fall.

For the 2J3KL cod before 1992 there was a reduction in the cold years, when capelin were later coming to shore. In more recent years there are little data available. Capelins are coming to the coast later during recent years than during the 1980s. However this picture is complicated by the presence of inshore capelin groups. There are bits and pieces of information which themselves are inconclusive, however none of the bits of information available are indicative of favorable conditions.
Northern cod appear to have a shortened feeding season because of capelin are coming to the coast later in the year. The bits and pieces of evidence indicate that the feeding conditions are likely worse for 2J3KL though for inshore fish it is likely that they can feed on capelin in the winter. Graham has shown that capelin in diet has decreased. Therefore, though there is more capelin on occasion, they do not seem to be preyed upon as much as they were.

Energy density

Shrimp abundance is high in 2J3KL but the value of shrimp compared to capelin is questionable. The tough carapace may affect digestibility, in that shrimp probably has a slower throughput rate than capelin. For example, it is uncommon to see cod stomachs as distended from feeding on shrimp as compared to capelin. Gorging on shrimp is not common but gorging on capelin was common historically. Further the nutrient content of shrimp and capelin is different. Capelin has 5.7 kJ/g and shrimp have 5.1 kJ/g but the fat content and vitamin difference are possibly important. The cod can feed on the shrimp and they can indeed find enough food. There are not huge differences in the energy density. In NFLD, the capelin vs shrimp question could be quite important.

Is there an increase in the abundance of the alternative predators on the prey? There is feeling from some of the fishermen that seals and whales have increased and this could be competition for capelin on the cod. Seals and whales are common and eat capelin. However, in this discussion there is an effort to focus on 1st order interactions that are limiting cod.

In general, there are fewer apparent problems with prey availability in areas other than 2J3KL. There have been changes in the proportion of food types in cod diets, and changes in the migration of cod, and changes in the feeding periods.

3.2.2 Environmental/Habitat limitation

H16: Growth is temperature dependent and temperature had been less favourable.

Temperature changes

All stocks being considered live in cold water and growth rates are expected to be low. Growth rate within the Gulf stocks seems to be lower than historically. There was poor growth in the early 1990's for all stocks, some stocks underwent observable changes at different times than others and were affected by differing degrees.

Declines in size at age were due to size selection (Size Selective Mortality)
Size at age. For the Southern Gulf stock, since the 1970s-1980s size at age has not recovered. However, the factors thought to influence recovery are indicative of recovery but recovery has not occurred. It is one hypothesis that genetic selection has played a role in the recovery. There might be a relationship between size selective fishing mortality and reduction in the size at age. This is not apparent / has not been looked at for stocks other than the Southern Gulf. This is not a conclusive argument, but an open question for review and additional inquiry. The larger question being, the stocks we have today are different because of the effects of fishing over the past 50 years. The paper by Sinclair et al may be unique to the Southern Gulf because of unique conditions there. It MIGHT be a local phenomenon.

Studies of mortality were recently started for 2J3KL cod.

H10: Oxygen content of the water has become lower resulting in increased mortality

The effects of oxygen upon growth, in general, this appears to be a problem related to the Gulf rather than 2J3KL cod. For the Northern Gulf in particular, lower oxygen concentration can cause mortality and decreased food consumption. The effects of decreased oxygen in the Northern Gulf suggest a cost to growth in the order of 20%. The level of oxygen appears to be decreasing for the estuary. This may relate to the lack of cod in 4T, or at least affect the distribution of cod in 4T. This is a change in habitat. In Northern Gulf, cod habitat loss could possibly affect distribution. This seems to stock specific.

3.3 Survival has been inadequate

3.3.1 Adult survival - predation

H18/H19: Impact of predation by marine mammals/impact of other predators has increased and reduced cohort survivorship.

For adult cod this is probably not a factor-small cod are eaten. Preliminary results from fatty acid signatures study suggest cod is low in grey seals diet.

2J3KL – For Northern cod, reduced survival due to seal predation is not only likely, but has happened, though the impact is difficult to measure quantitatively. This is an area of concern given it is a permanent situation. Fisherman observations – seal predation is definitely a factor even for larger sized cod (fisherman).

4TVn - Southern Gulf (fisherman) - most definitely a problem, some argue large fish are eaten but not accounted for. In the Southern Gulf, definitely a problem and could account up to 80% for the non recovery according to the fishermen. Regional experts note discrepancy between diet studies and reports from anecdotal observations (due to the fact that otoliths are not ingested). Harp seals likely a factor because present in the Gulf with cod in the spring (fisherman). But it is likely that grey seals remain the major predator in the Southern Gulf.

No other predator was mentioned as being significant by any participant.

3.3.2 Juvenile Survival - Predation

H18/H19: Impact of predation by marine mammals/impact of other predators has increased and reduced cohort survivorship.

4TVn and 3Pn4RS – It was pointed out that R/SSB has not been low in recent years and may have increased (supported by recruitment production observations in g/fish in both stocks). In Newfoundland it is likely average.

Marine mammals
4VsW – Studies indicate that the impact of seal predation is twice that of cannibalism in 4Vs, M due to seals 0.5, 0.25 for cannibalism, juveniles only. Most of the cod eaten by seals are 20-30 cm long. The full range of sizes eaten by grey seals in 4VsW is10-45 cm based on stomach contents.

Evidence supports no elevation of impact on juveniles beyond what it used to be. Not agreed to by fisherman, pointing out there are more seals now in 4T than before.

R/SSB could possibly increase in the no-seal situation. If M doubled in adults, it may have doubled in juveniles as well, part of it due to seal predation.

Otoliths study from stomach contents in grey seals indicated that they eat 10-55 cm cod. Half of the fish were measured to be less 31 cm. (4T, based on otolith sizes, only 14 measured). Latest estimations indicating consumption is between 19-39000 tons for grey and harp seals in 4T. It is estimated at 25000 tons for harps in NGSL (3Pn4RS).

As for other type of predators, we know very little about that. Large cetaceans eating fish can have an impact but we have no reliable estimate of the population size.

3.3.3 Physical Environment

H41: Physical environment conditions directly increase mortality rate of adult cod (winter lethal temperatures).

Unlikely.

H42: Physical environment affects the distribution/migration of adult cod.

For southern Gulf, marked catches in 4T area.

For northern Gulf, cold water temperatures in the late 1980s, early 1990s are not sufficient to explain the very deep winter depth distributions. For southern Gulf, the earlier fall migration does not appear to be linked to cold temperatures. Causal mechanisms for earlier fall migration of the 2 Gulf stocks are not well understood. Gadolife is examining oceanographic fields by month for southern Gulf cod and may shed some light on temperatures cod occupy throughout the year.

3.3.4 Trophic Limitation - Adults

H24: Timing of food availability has changed disrupting annual cycle of feeding/growth.

We don't know much about the timing of food availability for adult cod. We know a bit about capelin movements and that 4T cod does seem to have a shorter feeding season but we cannot say much else. We know that trophic limitation taken to its extreme will go beyond slower growth to the point on death but we cannot say that this has occurred

H37: Spatial distribution has changed, reducing availability to adult cod.
For the spatial limitation of prey same conclusion as for H24, i.e. there is not very much information about spatial distribution of prey and we cannot address it properly at present.

H38: Condition factor has been reduced for some or all of the year.

We already know that low growth was associated with poor condition. It has been previously discussed (in WD) that low condition leads to reduced swimming capacity and therefore they may become more susceptible to predation. Poor condition in the spring also leads to poor condition in the summer because they are in less than prime state to forage effectively.

3.3.5 Trophic Limitation - Juveniles

H22: Competitors for juvenile food have increased abundance or consumption.

Pelagics have increased in abundance particularly in the Gulf. There is not clear evidence that they are competitors with juvenile cod. Generally we have little definitive to say about this.

H24: Timing of food availability has changed.

In some places the euphausids are low in abundance and they can be an important juvenile cod prey. There has been a change in the size composition of the prey for juvenile cod. We have little info on this, especially where and what prey and where the juvenile cod are located.

H37: Spatial distribution of prey has changed.

No information on spatial distribution of prey. Could be happening but do not know.

H38: Condition factor has declined.

No information on condition factor on juveniles.

The information on these hypotheses may look at what has been put forward for adults.

3.3.6 Juvenile Survival – Fishing Mortality

H27: Mortality rates of juveniles have increased due to bycatch in pelagics and invertebrate fisheries.

For 4T, age 3 on SSB is survival is low in 90's mortality is not high. Northern Gulf like 4T.

2J3KL - juveniles are affected, they do not reach adults. Capelin and herring fisheries have declined (but cod juveniles have also declined). No fisheries that have large amounts of small fish as by-catch. More observer coverage could help.

In 4VsW there are no fisheries that could take juveniles.

H28: Mortality rates on juveniles have increased due to non-retention mortality in groundfish gears.

No information.

3.3.7 Juvenile Survival – Natural Mortality

H29: Natural mortality has increased, but mechanism is unknown.

No evidence of elevated M on juveniles. This may be a larger factor for 2J3KL and 4VsW.

3.3.8 Size Selective Mortality

H15&H23: intrinsic growth rates have been reduced, increasing mortality on a cohort.
No evidence of elevated mortality of juveniles (covered above).

3.4 Additional Issues

Salinity
Many experiments with adult cod at IML – low salinity (12-14 ppt) promotes growth; so not an issue over the range experienced in the wild.
But salinity may affect depth distribution of eggs. Reduced salinity at Station 27 – may affect egg distributions.

UV effects on eggs and larvae
Effects restricted to the top few meters – may have an impact on pelagic organisms near the surface, but not likely to be an effect on cod eggs since lower in the water column. Most eggs in NE GSL were 0-100m – wide distribution – UV not an issue.

Implications for Projections
There was much discussion of methods for integrating factors and producing medium term stochastic simulations. Trouble with stochastic simulations is in the details – other methodsa are available that aren't as demanding. Stochastic simulations are considered to be unhelpful in terms of adding too much variability into the predictions. It was pointed out that the FRCC has requested stochastic simulations - must respond to request for 5-yr stochastic simulation. In the end, deterministic projections were agreed upon as the best course of action.

Replacement recruitment at current F and F=0. The only processes that determine change in stock biomass is recruitment rate, body growth rate, maturation rate, survival rate. Is recruitment above replacement at current F and at F=0? Alternatively, deterministic forward projections with F=0 and current F.

For northern cod, know current weights-at-age, maturation rate.

Surplus production figures show no relation between surplus production per individual and F. Need to compare surplus production calculations with replacement recruitment calculations.

Have no mechanism for stochastic projection for 4VsW?

3Ps,4RS3Pn mixing issue is likely important to the recovery of the stocks
This is indeed important especially if it undermines the efficacy of tough decisions (e.g. moratoria) in one area while fishing continues in the mixed area; however, it is probably best to address this in the SSR rather than under hypotheses.

Seal consumption
It was proposed that seal consumption needs to be more strongly worded. i.e. it seems that we are unwilling to say that a cod killed by a seal is less important that a cod killed by fisheries.

Others argued that they feel that wording on seals is about as strong as we can make it given our evidence and that current conclusions are in fact very strongly implicating the seals in the lack of recovery.

4.0 Projections

Medium term projections were requested by the FRCC. Medium term was interpreted as a five year forecast and treatments of the data were standardized as much as possible. A letter was sent to the FRCC summarizing the results (see Annex 7).

4.1 4TVn

Given the low productivity, spawning biomass is expected to decline by about 6% with no catch in 2003 and decline by 16% with a TAC of 6,000 t.

Five year projections were conducted assuming three harvest conditions:
A) no fishery from 2003 to 2007
B) 2000-2002 exploitation rate (about 8%) for 2003 to 2007
C) 6,000 t quota for 2003 to 2007

Projections over this longer time period are more uncertain because there are currently no estimates for yearclasses that would contribute significantly to the biomass in the last years. It is also necessary to assume that a number of factors such as growth and natural mortality will not change.

The results of the projections indicate that the SSB will decline in the near term for all scenarios due to low incoming yearclasses. Only the no fishery scenario resulted in slowly increasing SSB at the end of the period. Projections under the current catch or exploitation rate scenarios resulted in continuous decline of the stock over the time period.

4.2 3Pn4RS

The results of projections for the northern gulf cod stock indicate that the SSB will decline slightly over the next five years even with no fishing. With an F of 0.336 or a longline TAC of 5,000 t per year, the SSB declines rapidly and continuously over the time period of the projection.

4.3 2J3KL

Projections for the northern cod stock inshore component indicate that the stock should grow slightly in the near term due to incoming recruitment but will decline in the future if exploitation rates remain at current levels. Even in the absence of fishing mortality, the SSB will not increase to the levels seen in 1998 with the current level of productivity in the stock.

4.4 4VsW

Two projection scenarios were examined for Eastern Scotian Shelf cod, both with a fishing mortality rate (F) of zero. Recruitment was assumed to be the average R/SSB for the last three years with a lognormal error of 0.5. One scenario used the natural mortality rate (M) of 0.8, estimated from RV calculations of the total mortality rate (Z), which probably underestimates M for the younger ages. The other projection used an M of 0.5 which was chosen by trial and error and represents the reduction in M necessary to achieve a stable population.

Under the M=0.8 scenario, the SSB declined continuously over the five year projection period, to about 25% of the 2002 SSB. When M was reduced to 0.5, the SSB was reasonably stable though still declining from the 2002 level.

5.0 Limit Reference Points

The Gadoid Reference Point Workshop participants identified three methods for determining five estimates of limit reference points for each Atlantic cod stock. The current meeting updated limit reference point estimates for some stocks that were previously assessed and used these techniques to estimate reference points for Eastern Scotian Shelf cod as well as cod in 3Ps.

Table 1: Limit reference points in tonnes for 5 Atlantic cod stocks

Method	4TVn	3Pn4RS	2J3KL	4VsW	3Ps
Sb50/90	70,000	74,000	307,000	12,590	39,000
NP50	80,000	200,000	800,000	53,990	43,000
Brecover	80,000	200,000	150,000	57,470	30,000
BH50	70,000	275,000	1,200,000	33,670	165,000
RK50	64,000	180,000	2,350,000	23,940	53,000
Brecent	72,000		28,000	10,220	65,422

For some stocks, there were different estimates of limit reference points depending on what methods were used to estimate SSB and recruitment. Eastern Scotian Shelf cod values for the Sb50/90 reference point varied from 12,590 t to 49,792 t depending on which model was used for population reconstructions. Similarly, for 3Ps cod the Sb50/90 point was estimated at 50,000 or 39,000 t and the 2002 estimates of biomass ranged from 65,000 to 110,000 t. The values in the Table 1 for 4TVn and 2J3KL were taken from the Gadoid Reference Point workshop while the values for the other stocks were presented at the current meeting.

The discussion focused on the various reference points and the estimates of current biomass. For three stocks the biomass is well below the reference points and the other two stocks are either at the reference point (4TVn) or near to it (3Ps). The point was made that the Serebreyakov 50/90 reference point was the one associated with the ability of the stock to produce average recruitment in good conditions, it is model free and there is some empirical evidence for it as a reference point. In general, the Beverton-Holt and Ricker curves were poorly defined and this influenced the reliability of their reference points.

The discussion also resulted in wording to define the concept of harm to a stock when below the reference point, reflecting the concept that when the estimated SSB is below the reference point, the productivity of the stock has suffered serious harm. The wording is as follows: The SSB is estimated to be below the conservation limit reference point for this stock. There is a high likelihood that the productivity of stocks below their conservation limit has suffered serious harm.

6.0 Key conclusions from the Zonal Assessment of some Atlantic cod stocks

- These stocks all declined from relatively high levels in the late 1970s and in the 1980s to such low levels in the early 1990s that commercial fishing moratoria were invoked.

- With the exception of cod on Eastern Scotian Shelf, fishing resumed on these stocks in the late 1990s, although at much reduced Total Allowable Catches (TACs).

- The recent status of these stocks, as determined during our meeting, is a follows:

6.1 Northern cod

- The research bottom-trawl surveys in both fall and spring indicate that the biomass of cod remains extremely low. The average trawlable biomass from fall surveys during 1999-2002 is 28,000 t, which is about 2% of the average during the 1980s.

- Hydro-acoustic estimates within two regions of the offshore (Hawke Saddle (2J) and the saddle along the 3K/3L boundary) were considered highly uncertain but suggest a combined biomass of less than 20,000 t.

- Estimates from the fall research bottom-trawl data indicate that mortality has been extremely high in the offshore since the moratorium and few fish survive beyond age 5.

- Indices of stock size from sentinel surveys, which are conducted with fixed gear in inshore waters, increased from 1995 to 1997-1998 and have since been declining.

- Catch rates from commercial logbooks declined from the opening in 1998 to the present.

- Catch rates in sentinel surveys and commercial fisheries have been consistently low in 2J and northern 3K. Since the fishery opened in 1998, catch rates have declined in both southern 3K and southern 3L, and have remained high only in northern 3L, most notably in southern Bonavista Bay and northern Trinity Bay. The opinions of fish harvesters, as recorded in responses to a written questionnaire sent to fish harvester committees throughout the stock area, are in general agreement with the above trends.

- Hydroacoustic surveys in January in Smith Sound (Trinity Bay) provided average indices of biomass that increased from 1999 to a peak of 26,000 t in 2001 and then declined to 20,000 t in 2003.

- Results of tagging experiments indicate a harvest rate close to 20% in the inshore in 2002 associated with a reported catch of 4,200 t. This harvest rate is in percent of exploitable biomass (approximately ages 4+), which was estimated to be 22,000 t in the inshore regions of 3KL. The exploitable biomass estimates increased during 1999-2001, but declined sharply in 2002. Most of the cod caught in southern 3L are thought to overwinter off southern Newfoundland (3Ps). The tagging studies provided evidence of natural mortality rates of 55% in 3K and 33% in 3L. These estimates are considered to be independent of unreported catch.

- A sequential population analysis (SPA) was conducted based on those cod in the inshore since the mid-1990s. The analysis incorporated catches during 1995-2002 and indices from the sentinel surveys and research vessel inshore strata. SPA estimates indicate that spawner biomass in the inshore increased from 1995 to 41,000 t in 1998, but has subsequently declined to only 14,000 t at the beginning of 2003. The estimate of 4+ biomass at the beginning of 2003 is about 30,000 t. Fishing mortality on older age classes has been increasing and is currently at approximately 35%, a level comparable to levels estimated during the stock collapse in the late 1980s and early 1990s.

- Both the SPA and a recruitment model indicate that the 1999 and 2000 year-classes are stronger than other year-classes since the mid-1990s, but are very weak compared to historic levels.

- The SPA indicates that the inshore spawner biomass has been decreasing since 1998 when the fishery reopened. Deterministic projections indicate that the stock will grow slightly in the short term as a consequence of the incoming recruits, but will decline thereafter if exploitation rates remain at current levels. Projections also indicate that even without fishing the spawner biomass will not grow during the next decade to the level reached in 1998, under the assumption that stock productivity does not increase above present levels.

- Consumption of cod by harp seals in 2000 is estimated from diet studies to have been about 37,000 t (95% confidence interval of 14,000 – 62,000 t). Most cod represented in such studies are small. Harp seals also prey on large cod by consuming only soft parts, and such predation has been frequently observed. Predation by hooded seals on cod has not been measured but is potentially large.

- The information on feeding by seals and trends in the harp seal population indicate that predation by seals is a factor contributing to the high total mortality of cod in the offshore and the high natural mortality of adult cod in the inshore
- When the spawner biomass in the stock as a whole approaches 150,000 t, the available data will be reviewed to determine appropriate spawner biomass limit reference points in keeping with a precautionary approach. Based on historic data, it is anticipated that appropriate conservation limit reference levels will be set at levels greater than 300,000 t for the stock as a whole. Recovery of spawner biomass to this level is expected to take many years. While the stock remains below this level, there is a high likelihood that the productivity of the stock will remain impaired.

6.2 Cod in the northern Gulf of St. Lawrence

In 2002-2003, the TAC was 7,000 t. As of December 31, 2002, 6,246 t were landed.

The abundance and spawning stock biomass remain low. The stock abundance increased between 1994 and 1999 but has declined since.

The recruitment estimates at age 3 have been declining since 1998 and are predicted to reach a historic low in 2003.

Energetic condition and growth have improved in recent years and fish now mature at older ages.

All three abundance indices based on research and sentinel trawl surveys increased from 1995 to 2000 but have declined since. The index from sentinel longlines increased from 1995 to 2001 but declined in 2002. This decline is most pronounced in southern 4R. The gillnet index appears to be stable.

Cod are increasingly concentrated inshore in 4R and thus are more available to inshore fisheries. A portion of the stock may be becoming less available to research vessel and sentinel trawl surveys but is monitored by sentinel longlines.

Natural mortality of adult cod remains high in this stock. Seal predation is a major factor contributing to this elevated mortality.

Unaccounted fishing mortalities may have increased in recent years due to under-reporting in the recreational fishery and gillnet discards in the commercial fishery.

Exploitation rate has been high since 1999.

With no fishing, the stock is expected to increase marginally in 2003. With a 1,500 t fishery, stock abundance will likely not change. Catches of 7,000 t (the TAC since 2000) is estimated to result in a decline of about 12% of the spawning stock biomass.

Spawning stock biomass is estimated to be below the conservation limit reference points for this stock. There is a high likelihood that the productivity of stocks below the conservation limits has suffered serious harm.

6.3 Cod in the southern Gulf of St. Lawrence

In 2002-2003, the TAC was 6,000 t. As of December 31, 2002, 5127 t had been landed.

The abundance and spawning stock biomass of the stock are low and declining.

All year-classes in the 1990s are estimated to be below average. Recent year-classes (1998-2000) are estimated to be the lowest on record since the early 1970s.

- Natural mortality remains higher than normal.

With no fishing in 2003, the spawning stock biomass would be expected to decline.

Rebuilding of spawning stock biomass over the next few years is unlikely, even with no fishery.

Spawning stock biomass is estimated to be below the conservation limit reference points for this stock. There is a high likelihood that the productivity of stocks below the conservation limits has suffered serious harm.

6.4 Cod on Eastern Scotian Shelf

- The stock has been under moratorium since 1993 and removals from bycatch and surveys have been less than 300 t per year since 1998.
- There are no indications that stock recovery is imminent.
- Since the moratorium, the spawning stock biomass has declined steadily in the absence of a fishery and is at or near its all-time low.
- Natural mortality on both adults and juveniles is extremely high.
- The size at age in the stock has been small but stable providing little growth production. The fish condition has improved in the last two years although it has not translated into improved growth.
- Recruitment has been very low for more than a decade. The 1999 year-class appears to be the largest since 1990 but is still substantially below the overall mean.

Spawning stock biomass is estimated to be below the conservation limit reference points for this stock. There is a high likelihood that the productivity of stocks below the conservation limits has suffered serious harm.

6.5 Reasons for lack of recovery

A number of cod stocks collapsed through the late 1980s to the early 1990s, prompting moratoria. At the onset of the moratoria, there were high expectations that cod stocks would recover rapidly. In the past decade these expectations were not realized, and recovery of cod stocks in the Gulf of St. Lawrence, Eastern Scotian Shelf, and north-east Newfoundland and Labrador Shelf did not occur. At the 2003 cod ZAP, participants considered over 40 possible reasons for the absence of recovery of the stocks. They concluded:

Expectations of rapid recovery were unrealistic, given the low spawning biomass and typical productivity of these stocks. Some stocks were far below any previously encountered stock sizes, and had to rebuild much further than in the past. Other stocks were at levels from which they had rebuilt previously, but that rebuilding occurred during a period of exceptionally high productivity.

All these stocks live in cold environments and show low productivity compared to many other cod stocks further south, and in the Northeast Atlantic. During at least the first half of the 1990s the ocean climate was particularly unfavourable for cod, and cod productivity worsened.

In addition to effects of fishing, adult mortality from other causes is very high for all these stocks. Although causes of this elevated mortality are not fully known, it was possible to conclude that:

- ☐ Estimates of cod consumed or otherwise killed by seals are high enough that such mortality contributed to the lack of recovery in all areas. The seal diet data indicate that the consumption is primarily of juvenile cod. However, stomach contents data underestimate the consumption of adult cod, because it has been observed that seals tend not eat the hard parts of large cod.
- ☐ For at least some of the stocks, the energetic condition of cod following spawning was particularly low in the early 1990s, and may have been low enough to result in mortality.
- ☐ A number of other factors were considered, but the evidence available does not suggest that they contributed importantly to the high adult mortality.

Mortality due to fishing is also a factor in the failure of these stocks to recover:

- On stocks where fisheries were reopened, removals reached levels that took or exceeded surplus production, contributing to the cessation of stock rebuilding and reversals of what increases had occurred.

- Discarding, misreporting, poaching, and unreported catches occur in both commercial and recreational fisheries. These practices should be eliminated, because they contribute to the lack of recovery. However, the likely scale of these removals is such that fixing them alone would not be sufficient to ensure recovery.

On the Eastern Scotian Shelf and offshore in 2J3KL, even though fisheries on cod have not been reopened, the stocks have declined further and remain very low. In offshore 2J3KL, there is uncertainty about the level of bycatch in a number of domestic and foreign fisheries. To the extent that such bycatch occurs, it is a factor in the failure of this stock to increase.

Size at age was low at the beginning of the moratorium for all stocks, contributing to slow initial rebuilding. Size at age has increased for 2J3KL through the 1990s, and in the Northern Gulf in the second half of the 1990s. Despite favourable conditions, size at age remains low for the southern Gulf and Eastern Scotian Shelf stocks, which limits the potential recovery of these stocks in the medium term.

Studies of the reproductive potential of cod stocks indicate that first time spawners are generally less successful than repeat spawners; fish in poor energetic condition have lower fecundity; and small spawners have shorter duration of spawning. All of these factors mean that larger, older spawners contribute more per kilogram to the reproductive potential of a stock.

- At the beginning of the moratorium all stocks had very few older fish and a high proportion of first time spawners, contributing to the slow initial rebuilding. Age structure has improved substantially in the southern Gulf and in inshore 3KL, somewhat in the northern Gulf, and remains contracted in the Eastern Scotian Shelf and offshore 2J3KL.
- The lack of older spawners and poor energetic condition of fish, for the periods when those circumstances occurred in each stock, contributed to the disproportionately low reproductive potential of the depleted spawning biomass.

In the southern Gulf, increasing abundance of mackerel and herring are expected to result in high predation on cod eggs and larvae in the coming years. This source of predation may also decrease cod productivity in the northern Gulf.

For stocks where the distribution of spawning components has been examined, severe reduction of the size of some spawning components or reduced area of spawning are contributing to the poor recovery of cod stocks.

Where maturation rates have been monitored, cod are maturing at younger ages. This has not resulted in recovery of any of these stocks.

Projections of stock trajectories in the coming five years suggest that some stocks may decline further even in the absence of fishing, and no stocks are likely to show more than marginal increases. All stocks are projected to decline further at current exploitation rates.

Taken together, these factors strongly suggest that there will not be a prompt recovery in any of these stocks.

Annex 1 – Agenda

Zonal Assessment Meeting-
Atlantic Cod
Delta Halifax, Halifax NS
Feb. 17-27, 2003

February 17 / 17 février	**09:30 – 18:00** **Assessment of Southern Gulf Cod (4TVn)**	**09h30 – 18h00** **Évaluation de la morue du sud du Golfe (4TVn)**
February 18 / 18 février	**09:00 – 18:00** **Assessment of Northern Gulf Cod (3Pn4RS)**	**09h00 – 18h00** **Évaluation de la morue du nord du Golfe (3Pn4RS)**
February 19 / 19 février	**09:00 – 18:00** **Assessment of Northern Cod (2J3KL)**	**09h00 – 18h00** **Évaluation de la morue du nord (2J3KL)**
February 20 / 20 février	**09:00 – 12:00** **Northern Cod cont'd** **13:00 – 18:00** **Eastern Scotian Shelf Cod (4VsW)**	**09h00 – 12h00** **Suite - Morue du nord** **13h00 – 18h00** **Morue de l'est du plateau néo-écossais (4VsW)**
February 21 / 21 février	**09:00 – 18:00** **Review of Hypotheses for Lack of Recovery**	**09h00 – 18h00** **Étude des hypothèses concernant le manque de rétablissement**
February 22 / 22 février	**Day of rest**	***Jour de repos***
February 23 / 23 février	**09:00 – 18:00** **Review of Hypotheses for Lack of Recovery**	**09h00 – 18h00** **Étude des hypothèses concernant le manque de rétablissement**
February 24 / 24 février	**09:00 – 18:00** **Review of Hypotheses for Lack of Recovery**	**09h00 – 18h00** **Étude des hypothèses concernant le manque de rétablissement**
February 25 / 25 février		

	09:00 – 12:00 **Re-runs of Stock Assessments (if needed)** **13:00 – 15:00** **Limit Reference Points for Atlantic cod and stock forecasts** **15:00 – 18:00** **Re-visiting Hypotheses for Lack of Recovery (if needed)**	**09h00 – 12h00** **Reprises – Évaluation des stocks (au besoin)** **13h00 – 15h00** **Points de référence limites pour la morue franche et prévisions des stocks** **15h00 – 18h00** **Dernier regard - Hypothèses concernant le manque de rétablissement (au besoin)**
February 26 / 26 février	**09:00 – 18:00** **Final Statements of Conclusions for each stock and Factors for Failure to Recover**	**09h00 – 18h00** **Relevé final des conclusions pour chaque stock et facteurs expliquant le manque de rétablissement**
February 27 / 27 février	**09:00 – 14:30** **Subgroup of Co-chairs and Key Assessors (to assemble documentation arising from meeting)**	**09h00 – 14h30** **Sous-groupe des coprésidents et des évaluateurs principaux (rassemblement de la documentation de la réunion).**

Annex 2 – Terms of reference

Zonal Assessment Meeting – Atlantic Cod
February 17-21, 23-26; 2003
Delta Halifax, Halifax NS

Objective 1 - Assess the status of four Canadian Atlantic cod stocks; Northern cod (2J3KL), Northern Gulf cod (3Pn4RS), Southern Gulf cod (4TVn), and Eastern Scotian Shelf cod (4VsW).

A. For each stock the meeting will review:
  - Information on catches, including best estimates of total removals by all fisheries. (C & P information on reliability of reported catch data will be important.)
  - Key indicators of stock status and trends (RV and sentinel surveys; commercial catch rates, size and/or age composition; etc).
  - Information as available from resource users with regard to recent stock status relative to historic stock levels.
  - Any NEW information on biological parameters of the stock (natural mortality, growth, fecundity, etc). Information reviewed and accepted in previous ZAPs or RAPs can be tabled without detailed review, if it is the most current information available on the biological parameter.
  - Formulation(s) of the analytical model(s). Sequential Population Analyses (SPAs) are desirable but not required if there are sound reasons why they are inappropriate for particular stocks. For all stocks, but particularly when an SPA is not appropriate, other analytical estimates of key stock status indicators such as biomass or fishing mortality (say, from swept area estimates for biomass or tagging data for exploitation rates) are encouraged to be submitted.
  - Other information on the physical and/or biotic environment considered important to interpreting trends in the indicators or estimates of stock status.

B. For each stock, the meeting will try to provide peer reviewed estimates with associated uncertainties regarding spawning and fishable biomass, total and fishing mortality (or exploitation rate), and such other stock characteristics as may be informative about stock status and/or consequences of management options. When it is not possible to estimate some of the key stock characteristics listed above, the provision of other indicators of stock status that would be informative to management is particularly important.

C. For Northern cod, Northern Gulf cod, and Southern Gulf cod, the meeting will try to advise on the risk that the stock would fall to or below the conservation (limit) reference points for SSB identified at the Gadoid Reference Point Workshop in November 2002. Risk averse catch levels could be identified relative to those reference points (For Northern cod, the Workshop identified a provisional benchmark to provide guidance towards the location of an appropriate biomass reference point, and that benchmark can be used in this context).

D. For each stock, the meeting will produce a point-form Statement of Conclusions by the end of the meeting. A Stock Status Report will be produced for each stock as well. Whether full drafts are reviewed at the meeting will depend on how quickly the meeting arrives at its conclusions about stock status.

Objective 2 - Consider the possible reasons why these stocks did not recovery fully in the years since the cod moratoria were first invoked. For those reasons that cannot be rejected, advise on the likelihood that the factor(s) responsible will reverse in the medium-term (3-5) years.

Explanation: A Planning Group has already developed an inventory of nearly 50 hypotheses for why these stocks have not recovered to historic levels in the past decade. Through discussion and preliminary consideration of available data, the list has been consolidated somewhat and organised into groups of related hypotheses. It is acknowledged that some hypotheses can only be addressed on the zonal scale, bringing together such data as are available from several places through the Atlantic Zone. Similarly, other hypotheses can be addressed fairly thoroughly for one stock, but weakly if at all for the other stocks. Still others may not be able to be addressed at all, due to absence of relevant data.

The meeting will consider the alternative hypotheses in full awareness of the limitations of the data and, in some cases, the analytical methods. It is unlikely that it will be possible to definitively reject any of the hypotheses as having no role whatsoever in the poor recovery, nor to assign a specific degree of responsibility for failure to recover to any single possible causal factor. Rather, the meeting shall operate in an advisory mode, evaluating the *weight of evidence* that, with regard to the weak recovery of these stocks, an hypothesised factor:

1) *could have been important.*
2) *could have been a factor but probably made a minor contribution.*
3) *was unlikely to have been a factor* or *at most made a minor contribution.*
4) *is not sufficiently documented or understood to make a conclusion about its role.*

Different conclusions about the importance of the various hypothesised factors can be drawn for different stocks. However, for hypotheses that can be addressed thoroughly with data from only one or two stocks, particular attention will be given to the strength of any justification to reject generalising the results to other stocks.

For all hypotheses in classes 1 and 2 of each stock, the meeting will consider if there is any reason to expect the factor to change its effect in the near future (3-5 years), and to the extent possible, specify the reason(s) for such expectations. Where there is no cause to expect a change in a factor, the meeting can assume that the best indicator of the near future is the present and recent past.

The meeting shall produce a Statement of Conclusions for each stock. As a minimum it will identify all hypothesised factors that were placed in class 1 for the stock, and the meeting's judgement regarding the likelihood of reversal of each. The Statement of Conclusions should also identify those hypothesised factors placed in class 3. What is said about those in classes 2 and 4 will depend on how informative the conclusions are regarding stock recovery.

Following the meeting one or more Overviews in the Stock Status Report series will be produced on the hypotheses regarding the weak recovery of cod stocks through the 1990s. The number and content of Overviews will be determined at the meeting, which will also specify the approval process for the text.

Objective 3 - Review medium-term simulations for the four stocks being assessed.

The FRCC has requested medium-term stochastic simulations for these four stocks. A Planning Group has taken "medium-term" to be a maximum of 5 years. These simulations should be carried out in as comparable a manner as appropriate for the four stocks. The meeting shall review:

1) The technical formulation of the simulations.
2) The initial conditions of the simulations.
3) The stochastic trajectories forecast for the stock.

The meeting shall prepare a Statement of Conclusions regarding the results of the simulations. It shall specify both any conclusions that can be drawn about the stock trajectories and the major limitations on interpretation of those trajectories.

If possible, the meeting should identify one or two simple indicators (e.g. research vessel numbers per tow, etc.) which could be used annually to monitor stock status, and should provide an indication of what would be considered a "recovered" state using such metric.

The meeting shall determine whether it is most efficient to prepare a separate SSR with the results of the stochastic simulations, or to include the results in the stock – by stock SSRs produced under Objective 1.

Annex 3 – List of participants

1. **Gilles Albert,** Association des pêcheurs MRC Pabok inc.
2. **Clifford Aucoin,** Nova Scotia / Nouvelle-Écosse
3. **Maurice Beaudoin,** Moncton University / Université de Moncton
4. **John Brattey,** DFO – Newfoundland / MPO – Terre-Neuve
5. **Willis Bruce,** DFO – Newfoundland / MPO – Terre-Neuve
6. **Jean-Claude Bourque,** Interpreter / Interprète
7. **Osborne Burke,** Nova Scotia / Nouvelle Écosse - EX FRCC
8. **Noel Cadigan,** DFO – Newfoundland / MPO – Terre-Neuve
9. **Martin Castonguay**, DFO – Quebec / MPO – Québec
10. **Gilles Champoux,** A C P G
11. **Nancy Chen,** DFO – Newfoundland / MPO – Terre-Neuve
12. **Ghislain Chouinard,** DFO – Quebec / MPO – Québec
13. **Frank Collier,** Association des Pêcheurs de la Basse-Côte Nord
14. **Linda Currie,** DFO – Gulf / MPO – Golfe
15. **Cyril Dalley,** Newfoundland and Labrador / Terre-Neuve-et-Labrador
16. **Christopher Darby,** The Centre for Environment Fisheries & Aquacultre Science (C.E.F.A.S.)
17. **David Decker,** Fish, Food and Allied Workers Union (FFAW) - Newfoundland
18. **Tom Dooley,** Department of Fisheries & Aquaculture, Newfoundland and Labrador
19. **Daniel Duplisea,** DFO – Quebec / MPO - Québec
20. **Jean-Denis Dutil,** DFO – Quebec / MPO – Québec
21. **Paul Fanning,** DFO – Maritimes / MPO – Maritimes
22. **Alain Fréchet,** DFO – Quebec / MPO – Québec
23. **Johanne Gauthier,** DFO – Quebec / MPO – Québec
24. **Brian Giroux,** Nova Scotia / Nouvelle-Écosse FRCC (at least was on it)
25. **Serge Gosselin,** DFO – Quebec / MPO – Québec
26. **Pierre Haché,** Pecherie Mylene
27. **Jorgen Hansen,** DFO – Maritimes / MPO - Maritimes
28. **Donnie Hart,** Nova Scotia / Nouvelle-Écosse
29. **Réjean Hébert,** DFO – Gulf / MPO – Golfe
30. **Frank Hennessey,** PEI Groundfish Association EX FRCC
31. **Einar Hjorleifsson,** Iceland – Islande
32. **Jackie House,** Fish, Food and Allied Workers Union (FFAW) – Newfoundland
33. **Jeff Hutchings,** Dalhousie University
34. **Harvey Jarvis,** Fish, Food and Allied Workers Union (FFAW) – Newfoundland
35. **Doug Johnson,** Fisheries Resource Conservation Council (FRCC) / Conseil pour la conservation des ressources halieutiques (CCRH)
36. **Joe Kennedy,** Provincial Representative – Newfoundland and Labrador / Représentant provincial - Terre-Neuve-et-Labrador
37. **Jean Landry,** DFO – Quebec / MPO – Québec
38. **Dan Lane,** University of Ottawa – FRCC / Université d'Ottawa – CCRH
39. **Dario Lemelin,** Provincial Representative – Quebec / Représentant provincial – Québec (FRCC)

40. **Brian Lester,** DFO – NCR – Fisheries Management / MPO – RCN – Gestion des pêches
41. **George Lilly,** DFO – Newfoundland / MPO – Terre-Neuve
42. **David MacEwen,** PEI Dept. of Fisheries, Aquaculture, and Environment
43. **Dawn Maddock-Parsons,** DFO – Newfoundland / MPO – Terre-Neuve
44. **Rory McLellan,** Prince Edward Island / Île-du-Prince-Édouard
45. **Robert Mohn,** DFO – Maritimes / MPO - Maritimes
46. **Corey Morris,** DFO – Newfoundland / MPO – Terre-Neuve
47. **Eugene Murphy,** DFO – Newfoundland / MPO – Terre-Neuve
48. **Loretta O'Brien,** Northeast Fisheries Science Center – USA
49. **Michael O'Connor,** National Sea Products
50. **Louis Pageau,** Association des Capitaines Propriétaires de la Gaspésie (ACPG)
51. **Guy Perry,** Fish, Food and Allied Workers Union (FFAW) - Newfoundland
52. **Gloria Poirier**, DFO – Gulf / MPO – Golfe
53. **John Pope,** NRC Europe Ltd – UK FRCC
54. **Jake Rice,** DFO – NCR (Co-chair) / MPO – RCN (co-président)
55. **Dale E. Richards,** DFO – Newfoundland / MPO – Terre-Neuve
56. **Denis Rivard,** DFO – NCR (Co-chair) / MPO – RCN (co-président)
57. **Amélie Rondeau,** DFO – Gulf / MPO – Golfe
58. **George Rose,** Marine Institute of Memorial University of Newfoundland FRCC
59. **Max Sexton,** Newfoundland and Labrador / Terre-Neuve-et-Labrador
60. **Peter Shelton,** DFO – Newfoundland / MPO – Terre-Neuve
61. **Jason Spingle,** Fish, Food and Allied Workers Union (FFAW) – Newfoundland
62. **Don Stansbury,** DFO – Newfoundland / MPO – Terre-Neuve
63. **Rick Stead,** DFO – Newfoundland / MPO – Terre-Neuve
64. **Lloyd Sullivan,** Newfoundland and Labrador / Terre-Neuve-et-Labrador
65. **Doug Swain,** DFO – Gulf / MPO – Golfe
66. **Rhéal Vienneau,** DFO – Gulf / MPO – Golfe
67. **Willis Bruce,** DFO – Newfoundland / MPO – Terre-Neuve
68. **Maureen Yeadon,** Yeadon Consulting – Nova Scotia ex FRCC – MACO

Annex 4 – Hypotheses Regarding Cod Rebuilding

		Northern Cod	Northern Gulf Cod	Southern Gulf Cod	Eastern Scotian Shelf	Comments
1.1	**Recruitment has been inadequate**	S - R plot: From SPA, not sure if will have something more recent than 1993. For surveys, gear change (1995) creates uncertainty. **[1]**	S - R plot supplied	S - R plot **[1]**	S - R plot **[1]**	This is metric to monitor recruitment
H1	The Spawning Biomass is very low. (i.e, there is a stock recruit relationship, and the stock is way down on the ascending limb).	From all historic data, spawning biomass clearly exceedingly low. **[1]**	Yes, see ref #20 [A-1]	yes (Chouinard et al. 2002) **[1]**	S-R as well as time series plots of R and SSB **[1]**	
H47	Patterns of distribution in space and time have changed, even of the mechanisms causing the changes cannot be documented, and the consequences of the new patterns are not known (WEAK explanation of anything).	Distribution has changed. Hypothesis that eggs not being placed into advantageous area (right site hypothesis) **[1]**	Distribution has changed, adults exit the gulf in winter, leaving the immatures behind (ref #4). In early 90's fish were found in deeper waters and more to the south (Ref #5, 7, 9, 17, 21). This may have links with the mixing issue. **[A-1]**	Relevance of this to recruitment is unclear. Changes in distribution during feeding season between low and high periods documented (Swain and Wade 1993). Progressive east-west change in distribution not explained. The east/west shift may reflect change in the relative strength of stock components (not yet investigated; no strong evidence for substock structure) which could have implications for recruitment. **[1]**	maps showing patterns have changed are available, no explanation of effect on recruitment **[1]**	

		Northern Cod	Northern Gulf Cod	Southern Gulf Cod	Eastern Scotian Shelf	Comments
1.1.1	Recruitment Rate (R/SSB) - If recruitment is low in an absolute sense, has the recruitment rate (recruits per spawner) declined?	To be explored. See 1.1.	There was a peak in survival rate in 1994 to 1996 (Ref # 20)	No. However, recruitment rate appears to be density-dependent. Rate is not low relative to 1950s and 1960s, but may be lower than expected at a low stock size. There is also an indication that the rate may be low for the last year-class estimated - 1999. This will be checked in this year's assessment	R/SSb from 3 sources, SPA, Fu Mohn Fanning and RV	
1.1.1.1	Early Life Stages (Egg and Larval)					
H8	Physical oceanographic conditions for development are less favourable than they used to be. (We would have to document which oceanographic properties have changed – temperature, salinity, etc. It would be helpful but not essential to also have a mechanism that linked the property to successful development.).	Changes in temp, salinity, stratification have occurred; will be documented. Mechanisms not well understood. **[2]**	Large volume of the Cold Intermediate Layer may affect egg and larval development and recruitment. Eggs buoyancy (a function of egg size and organic content - linked to females' nutritional condition or size and reproductive status) deterines their vertical distribution. Large proportion of eggs can be found in the cold water layer with possible negative consequence on development and survival. (Ref # 22) **[A-2]**	Swain et al Res Doc 2000/147: Evidence for a slight but significant effect of timing of ice-out on recruitment success (intermediate dates are best). Also a suggestion that cooler springs may be better, but not significant after accounting for autocorrelation. However, analysis didn't include the recent years when springs were very warm and year-class strength apparently very low. **[1 Swain et. al. 2000 CSAS Res Doc 2000/147]**	temperature changes known (Misaine anomalies), stratification, no linkage to local ELS, RIVSUM **[2]**	

		Northern Cod	Northern Gulf Cod	Southern Gulf Cod	Eastern Scotian Shelf	Comments
H9	Transport paths have changed such that eggs and larvae travel through or end up in areas less suitable for development. (As with 8, we would have to document the changed paths, and the test would be stronger if we had a mechanism by which development was impaired).	No information to suggest this. **[3]**	Moleling of egg and larvel dispersion in 4R generally has a northward drift. Juvenile deposition is thaught to be along the Belle-Isle approaches. This area is known for important upwelling which may affect year-class strangth. (Saucier, Pers comm) **[B-3]**	Data from mackerel egg survey suggest striking change in cod egg/larval distribution in late 1980s and early 1990s. Could check the more recent surveys to see whether this is still the case. Joel Chassé is also working on IBM using physical forcing **[2? unless there's time to look at egg/larval distributions 1982-2002]**	Frank and Thompson on retention/ advection indices, stratification, New work by Petrie on changes in sea level suggest increased long shelf flow since mid-80's **[2]**	
H10	Oxygen content of the water has become lower, leading to increased direct mortality.	Data are available. No indication of mortality due to low oxygen. **[1]**	Not thaught to be an issue in the eastern portion of the stock area, may be of an issue in the deeper waters of western 4S. This may affect cod distribution, food intake. **[A-2]**	very unlikely given the shallow nature of southern Gulf - ruled out **[1 not an issue at the depths in the Magdalen Shallows]**	O2 data but no analysis, could have ESS time series **[1 C not likely an issue]**	Oxygen deprivation and/or energetic depletions leading to (post-spawning) mortality - Dutil & Lambert

		Northern Cod	Northern Gulf Cod	Southern Gulf Cod	Eastern Scotian Shelf	Comments
H11	Predation on eggs and larvae has increased. (We would have to document which predators, ideally with both coincident trends in populations and diet data. Having both would be much stronger than having either alone. Do we want three separate hypotheses for Marine Mammals, pelagic fish, and larger invertebrates as predators?).	No direct data known. Observations from elsewhere indicating shrimp might be predators. Biomass of planktivorous fish might be down. **[1 some information on predators, but not their feeding]**	No direct data. Predators of eggs and larvae may include shrimp, crabs and pelagics. **[B-3]**	Evidence for link between abundance of pelagic fish and survival (Swain and Sinclair 2000). Presumably predation on eggs and larvae would be related to pelagic fish. There could also be an effect of competition with pelagic fish, but the two types of effect would be indistinguishable in many analyses. Another issue for recruitment would be reduced juvenile survival. A hypothesis here is seal predation. The analyses in ResDoc 2000/147 indicate: 1. a negative effect of pelagic fish biomass (currently high) on "pre-recruit" survival 2. a negative effect of adult cod biomass (currently low) on "pre-recruit" survival 3. seal abundance was not a significant covariate in the S-R relationship once other ecosystem factors were controlled for. **[1 Swain et. al. 2000 CSAS Res Doc 2000/147; Swain & Sinclair 2000 CJFAS 57(7)]**	graphs and data showing herring and other planktivores increased, **[1 some information on predators but not their feeding]**	
H14	Competitors for larval food have increased their abundance and/or consumption of shared foods, reducing the cod food supply, allowing consequences in 12 and/or 13.	Availability of relevant data to be checked (Pepin) **[1 some information on predators, but not their feeding]**	Not known **[B-3]**	unknown and indistinguishable from H11 in retrospective analyses of the effect of pelagic fishes **[1 not distinguishable from H11 re. pelagic fish]**	planktivores increased but no diet **[1]**	

		Northern Cod	Northern Gulf Cod	Southern Gulf Cod	Eastern Scotian Shelf	Comments
1.1.1.2	Reproductive Biology					
	Maturity Schedules	Age at maturity has declined for both sexes.			data exists from spring surveys	
H2	Kilogram for kilogram small/young spawners are less effective (fecundity and/or viability of products) spawners than old/large spawners, and the age/size composition of the SSB is very young/small.	Age/size composition in offshore highly truncated. Not so inshore. **[1 difference between inshore and offshore]**	The shift in maturity to smaller size fish produces less eggs per fish (Refs #13, 20). **[A-2]**	ResDoc 2000/148: - no relationship between mean age or size of spawners and recruitment rate - mean age of spawners is near highest value in 50-yr time series **[1 Swain & Chouinard CSAS Res Doc 2000/148]**	show changes in mean wt in SSB both VPA and RV **[1]**	Trippel et.al. would do an overview of reproductive potential.
H3	The condition of the spawners is poorer than "usual", such that per capita or per kg fecundity is impaired (either fewer eggs per kg or lower lipid/energy content per egg).	Condition does not appear unusual (DFO). Condition poor offshore (Rose-MUN). **[1]**	Condition in the mid-90's were so low that there may have been mass mortalities at sea. Laboratory reared fish are shown to die at those condition levels (Ref ??) **[A-1]**	Condition in September has been higher in the 1990s than the average for the 1980s but are lower than in the last period when the stock was low (mid-1970s), Chouinard and Swain 2002.). However, there is a very strong seasonal cycle in condition, so the Sep time series may not be representative of trends in annual minimum condition. **[1]**	summer condition trend, spring condition trend, no local link to fecundity **[1]**	
H4	The abundance of spawners is reduced so low that spawning behaviour has been disrupted ("Allee effect"), disproportionately reducing the fecundity per kg of SSB. (Behavioural depensation – even if the specific mechanisms are not known).	Offshore: possible, but how to test? Inshore: unlikely, because dense aggregations **[3]**	Unknown in the Northern Gulf. **[A-1]**	Unknown but no indication that this is a problem in sGSL **[1? evidence of depensation in S-R relationship]**	Frank and Brickman 2000 **[1?]**	

		Northern Cod	Northern Gulf Cod	Southern Gulf Cod	Eastern Scotian Shelf	Comments
H7	Human activities that interfere with successful spawning now are occurring in cod spawning areas, at levels greater than they did when recruitment was better.	Human activities thought to be less now. **[2]**	The creation of a spawning box to halt all groundfish fishing off Bay St. George (4Rd) in 2002 (April 1 - June 15) should reduce this possibility. **[B-3]**	Unknown, groundfish fishery activities are reduced, snow crab fishery (traps) takes place during spawning period **[1]**	fishing effort is very low, seismic increased since collapse? **[2]**	
H44	The life history of cod has changed (due to directional selection by fishing?) such that energy allocation among reproduction and growth is different. (It would be necessary to carry on to population dynamics consequences of the changes).	Age of maturity lower. Mechanism not known. Currently being studied, but no results for ZAP. **[2]**	Age of maturity lower, no indication of redirection of energy. **[B-2]**	Evidence of size-selective effects on growth (Hanson and Chouinard 1992; Sinclair et al. 2002) **[2]**	can show reduced growth and smaller spawners **[2]**	
1.1.1.3	Spawning Components					
H5	Individual spawning components have been greatly reduced within the population, with detrimental impacts on stock productivity. (Spatial depensation - We could but would not have to specify the mechanism by which productivity is impacted. Just documenting depleted components would probably be accepted as a reason why recruitment could be impaired).	Spawning components greatly reduced, but no evidence that genotypes lost. **[1 all (?) components reduced offshore; inshore uncertain - possibly increased]**	There are anectotal information that spawning did occcur in the past around Anticosti, currently very little fish is seen in the area (Needler survey in August, 2 sentinel surveys in July and October). Otolith trace element analyses are foreseen to elucidate this. **[B-3]**	Unknown **[? no evidence for loss of components, may be a change in the relative importance of eastern vs western components]**	Frank, Drinkwater and Page 1994, Taggart various refs **[1]**	

		Northern Cod	Northern Gulf Cod	Southern Gulf Cod	Eastern Scotian Shelf	Comments
H6	Spawning now takes place in non-traditional places, resulting in less effective release of reproductive products. (We would probably have to provide more in the way of causes and mechanisms than in 4. Is the timing of migration disrupted? Are suitable water temperatures now distributed differently than in the past? Are the places where the eggs are likely to be transported now different from where they used to be transported?).	No knowledge that this is so. However, spawning is greatly reduced in traditional places. **[3]**	The main sopawning area has been well identified in 4 different surveys (off Bay St. George in April May - 4Rd). However, from a questionnaire directed to fishermen there would be some limited spawning in the eastern portion of 4S and in 3Pn **[B-3]**	Unknown but no evidence of major changes in water temperature regime or currents. Evidence for change in egg/larval distribution in late 1980s. Might want to check more recent data. Delayed spring migration in late ice years. **[2? unless there's time to look at egg/larval distributions 1982-2002]**	changes in distribution of spawners may be described, effect on recruitment unknown **[3]**	
1.2	**Growth and production have been inadequate**					
H44	The life history of cod has changed (due to directional selection by fishing?) such that energy allocation among reproduction and growth is different. (It would be necessary to carry on to population dynamics consequences of the changes).	Age of maturity lower. Mechanism not known. Currently being studied, but no results for ZAP. **[3]**	see comment to H45 **[B-2]**	see comment to H45 **[3]**	Same as wrt reprod. [3]	
1.2.1	**Adult Growth**	Age 7 weight? No decline, but virtually no animals offshore. Length at age? No decline in recent years. Condition factor: No decline in recent years. **[1]**	See figure on weights at age, it has improved recently. The condition is generally stable with a slight increase in 2002.	Age 7 weight? Length at age? Condition factor **[1]**	Age 7 weight? Length at age? Condition factor - all are available **[1]**	

		Northern Cod	Northern Gulf Cod	Southern Gulf Cod	Eastern Scotian Shelf	Comments
1.2.1.1	Trophic Limitation - Energy supply to cod is limited by one or more effect of changes in food abundance, especially for key prey species, or food quality including species composition and prey energy density. Trophic limitation may be reducing growth, increasing mortality, or reducing spawning success. (to subsume H20, H21, H25 H34, H36 for juveniles and adults, H12 H13 for ELS)	Has been suggested that insufficient capelin, but no estimates of capelin biomass. For juveniles, concern that macrozooplankton (esp. euphausiids) may be less abundant. No direct information **[1]**	Has been suggested that insufficient capelin, but no estimates of capelin biomass. For juveniles, concern that macrozooplankton (esp. euphausiids) may be less abundant. No direct information	No information readily available, but doesn't seem likely - cod abundance is low and many of their prey (e.g., herring, shrimp) are at high levels of abundance. Evidence that fall migration is earlier now. Cause unknown. Results in a shorter feeding season. Euphausids are less prevalent in diets but fatty fish such as herring are highly prevalent (Hanson &Chouinard,2002) **[1? time series of cod diets - Hanson & Chouinard 2002; time trends of some of the important prey are available]**	increasing forage for adult cod, high oil species **[1]**	
	Fish condition/size/growth to assess trophic limitation	For H24 to H38: DFO survey data showed decline in condition in early 1990s, but no problem since. Data from Rose (MUN) indicates there may be some problem offshore compared to inshore. This will have to be resolved. Mechanisms can then be discussed. There is concern that even if capelin is not limiting at current cod stock level, it may become so if cod started to increase.	The condition was high in the late 80's and has declined substantially in the early 90's. Inshore fish have a better condition than fish caught by the groundfish surveys. The inshore feed heavily (stomach fullness) on fish (high energy per gram) while fish caught in the surveys feed less and eat more invertabrates (less energy per gram)			

		Northern Cod	Northern Gulf Cod	Southern Gulf Cod	Eastern Scotian Shelf	Comments
	For southern Gulf cod, the decline in size at age (occurred in late 1970s and early 1980s) appears to be due in part to density-dependent growth - this could be seen as a component of the previous hypothesis.	[3]	**[B-2]**	**[1 Sinclair et.al. 2002a,b CJFAS]**	[2]	
	Declines in size-at-age were due to changes in size selection.	[3]	**[B-2]**	**[1 Sinclair et.al. 2002a,b CJFAS]**	[2]	
	Changes in migration timing have reduced duration of the feeding season (maybe grouped under trophic limitation?)	[1]	**[B-2]**	**[1 Comeau et.al. 2002 ICES J Mar Sci]**	[3]	
1.2.1.2	Environmental/Habitat Limitation	Temperature, Salinity, Oxygen	Temperature, Salinity, Oxygen	Temperature, Salinity, Oxygen	Temperature, Salinity, Oxygen	
H16	Growth is temperature dependent and temperatures have been less favourable in recent years.	Temperature cold in 1st half-1990s; warmer since. Evidence that growth is temperature-dependent. New analyses required for recent years. **[1]**	A series of very severe winters has been seen for about 15 years in a row. This has increased substantially the CIL and may be linked with poor growth. Cod overwinter under the CIL and must cross it inorder to feed inshore in the summer. **[B-2]**	Effects of temperature small in adult fish **[1 Sinclair et. al. 2002 CJFAS, Swain et. al. 2002 JFB]**	data exists on T, S and growth **[1]**	
1.2.2	Juvenile Growth	Age 1,2,3 weight? Length at age? Condition factor: Length-at-age for ages < 3 problematic because of change in gear in 1995. Weights not well determined for fish < about 20 cm. Information to be checked.	Not monitored.	Age 1,2,3 weight? Length at age? Condition factor	Age 1,2,3 weight? Length at age? Condition factor	

		Northern Cod	Northern Gulf Cod	Southern Gulf Cod	Eastern Scotian Shelf	Comments
1.2.2.2	Environmental/Habitat Limitation	Temperature, Salinity, Oxygen	Temperature, Salinity, Oxygen	Temperature, Salinity, Oxygen	Temperature, Salinity, Oxygen	
H16	Growth is temperature dependent and temperatures have been less favourable in recent years.	Temperature cold in 1st half 1990s; warmer since. See 1.2.2 regarding limitations of data. **[1]**	See H16 **[B-2]**	Effect of temperature on adult growth appears to be small (Sinclair et al. 2001). However, effect may be stronger on juveniles (Swain et al 2003). At any rate, temperature conditions appear to be favourable in the most recent years **[1 Swain et. al. 2002 JFB]**	same as for adults with concern about estimating growth of partially selected ages **[1]**	
1.3	**Survival has been inadequate**					
1.3.1	Adult Survival	Z plots	Z plots supplied	Z plots	Z plots	
1.3.1.1	Total Mortality (RV Z's)	RV Z's extremely high **[1]**	RV Z's extremely high	**[1]**	**[1]**	
1.3.1.2	Fishing Mortality (recent assessments)	F plots	F plots supplied	F plots	F plots from VPA, FMF and RV rel F	
H30	Fishing mortality due to recorded catches (by fleet sector) has slowed population growth.	Exploitation rates will be calculated for the inshore from tagging studies. Offshore is more problematical. Easier to explore if accepted SPA. **[1]**	F in 2001 was 0.5 (Ref #20). **[A-1]**	yes though little or no population increase expected even in the absence of fishing given currents rates of recruitment and M **[1]**	yes **[1]**	
H31	Mortality due to unreported catches and/or discards has slowed population growth.	Attempts will be made to estimate the magnitude of unreported catches and discards from some fisheries. There are no estimates from poaching, which may be extensive. See also H30. **[2 speculation]**	The important trawling activities prior to the moratorium may have led to unaccounted mortality (FRCC). **[B-2]**	Possible but likely small given controls on fishery **[3 except my comment on whether it's likely that this could have a large impact given recent effort levels]**	H31 and H32 are indistinguishable in most cases, FMF speculates on this **[C-2 since moratorium]**	

		Northern Cod	Northern Gulf Cod	Southern Gulf Cod	Eastern Scotian Shelf	Comments
H32	Mortality due to non-retention in fishing gears has slowed population growth.	Can such mortality be inferred from studies elsewhere? See also H30. **[3]**	Was the case in the shrimp fishery before the Nordmore grid (Ref #6). **[B-2]**	not likely significant **[3]**	**[3]**	Non-catch fishing mortality - Frechet.
1.3.1.3	Natural (?) Mortality	M plots	M plots supplied	M plots	M plots = Z-F?	
H29	Natural mortality has been documented to have increased, but the mechanism is unknown.	Natural mortality may be high. Unknown mechanisms may be operational. **[1]**	M is still high (estimated through Sinclair method and ADAPT). **[A-1]**	Yes, although not demonstrated, increase predation by seals is the hypothesis **[1]**	yes **[1]**	
H46	Post spawning mortality has increased, whether or not the mechanism responsible for the increase can be documented. (More convincing, of course, if it can be).	No analyses have been conducted. **[3]**	relate spawning condition to Dutil and Lambert levels? **[B-2]**	unknown, no evidence **[3]**	relate spawning condition to Dutil and Lambert levels? **[3]**	Oxygen deprivation and/or energetic depletions leading to (post-spawning} mortality - Dutil & Lambert.
1.3.1.3.1	Predation					
H18	Impact of predation by marine mammals has increased, and reduced cohort survivorship compared to historic rates. (Should be supported by both population and diet data.).	Consumption of adult cod by seals observed in inshore. Impact on populations not quantified. **[2]**	Likely. Correlation between estimated M and grey seal abundance in the nGSL. Caveat is that increase in M is for large adult cod whereas belief has been that seals eat mostly juvenile cod. **[A-2]**	Likely. Correlation between estimated M and grey seal abundance in the sGSL. Caveat is that increase in M is for large adult cod whereas belief has been that seals eat mostly juvenile cod. **[1 Chouinard et. al. 2002 ICES CM 2002/V:11]**	Mohn and Bowen, VPA, FMF, diet QFASA? **[2]**	
H19	Predation by a specified other predator or suite of predators has increased, and reduced cohort survivorship compared to historic rates. (Should be supported by both population and diet data.)	No suggestion of this in the literature. **[3]**	Not known. **[B-2]**	no **[3]**	little known predation on adult cod **[3]**	

		Northern Cod	Northern Gulf Cod	Southern Gulf Cod	Eastern Scotian Shelf	Comments
1.3.1.3.2	Physical Environment					
H41	Physical environmental conditions have altered in ways that directly increase the mortality rate of adult cod (winter lethal temperatures or other mechanisms).	No suggestions in the literature. **[3]**	Not known. **[B-2]**	Unknown - no indication that this is so **[3?]**	not reasonable for ESS - Drinkwater **[C-2]**	
H42	Physical environmental conditions have altered in ways that affect the distribution and/or migration of cod, such that they spend parts of their annual cycle in non-traditional (can it be demonstrated less suitable) places. (whether or not we can document consequences of being displaced from traditional locations)	Such changes occurred in early 1990s. Not so apparent now, because so few fish anywhere in offshore. **[3]**	Migration routes have changed (deeper, earlier) and can be explained partly by colder intermediate water temperatures (Refs # 7, 9, 12, 15, 16, 17, 18, 19). Has been shown to ba a factor in the 3Pn longline fisheries (Ref # 5). This may also play a role in the mixing with 3Ps. **[B-2]**	Evidence that fall migration is earlier now. Cause unknown. Results in a shorter feeding season **[3? no indication that this has occurred]**	can show changes in distribution (RV and fishery) no linkage to less suitable. **[2]**	Body burdens of contaminants & pollutans - Yates (Fairchild, Payne, Gobiel, Puize)
1.3.1.3.3	Trophic Limitation (via Condition?)					
H24	Timing of food availability has changed such that annual cycle of feeding and growth are disrupted. (This would require documenting change in timing such as earlier or later spring bloom, and would be helped documenting some relationship of feeding or growth to the food items whose temporal availability has changed.)	For H24 to H38: DFO survey data showed decline in condition in early 1990s, but no problem since. Data from Rose (MUN) .ndicates there may be some problem offshore compared to inshore. This will have to be resolved. Mechanisms can then be discussed.There is concern that even if capelin is not limiting at current cod stock level, it may become so if cod started to increase. **[1]**	Not known. **[B-2]**	see comment on H42 **[1? change in migration timinng - Comeau et. al 2002, but consequence (if there is one) would be H38]**	no idea **[3]**	

		Northern Cod	Northern Gulf Cod	Southern Gulf Cod	Eastern Scotian Shelf	Comments
H37	The spatial distribution of prey has changed in ways such that even if amounts have not declined, availability to cod has declined.	**[1]**	Shrimp is a key prey in the Northern Gulf, it has expanded such that shrimp can be found almost everywhere in the nGSL. **[B-2]**	no significant change except for euphausids and increase in herring **[3 no indication of this]**	forage species distribution wrt cod in RV? **[3]**	Food quantity and quality for adults was going to be dealt with stock by stock, with a single good hypothesis from Paul Fanning replacing H35, H36, H37.
H38	Condition factor has been reduced for some or all parts of the year, whether or not any changes in feeding conditions have been documented. (This would benefit from some demonstrated consequences of poorer condition on growth, survivorship, or fecundity.)	**[1]**	The seasonal cycle of condition is greater than the annual variabilities, this needs special attention in the monitoring. Monthly data is just starting to be monitored in fixed gear sentinel. **[B-2]**	Condition is typically low in spring (Schwalme and Chouinard, 1999). Condition has been generally lower recently than in the previous period of low abundance (mid-1970's) Chouinard and Swain 2002) **[1]**	plots of CF but only Dutil and Lambert to speculate on consequences **[1]**	
1.3.2	Juvenile Survival					
1.3.2.1	Total Mortality (RV Z's)	RV Z's have been very high since moratorium. **[1]**	Thought to be high recently (seals), not due to the fishery, the Decker plan which is fixed gear only and catches large fish (above age 7).	**[NO - will treat as a component of R/SSB]**	likely to be negative unless q-corrected **[1]**	
1.3.2.2	Fishing Mortality (recent assessments)					
H27	Mortality rates of juveniles have increased due to bycatch and discards in fisheries for small pelagics (capelin, herring?) or invertebrates (shrimp). (Necessary to document bycatch rates and effort in the fisheries).	Actual numbers discarded can be estimated for some fisheries, but not all. Mortality rate more difficult. **[1]**	Not suspected to be high unless post-selection mortality from the Nordmore grid is high (unknown). Can be an issue with the witch by-catch in Danish seiners. **[B-3]**	no evidence, increases in mesh sizes in 1990's would have reverse effect **[3]**	possible with shrimp and herring gill net, some data exists (Power, Koeller and Showell) **[2]**	

		Northern Cod	Northern Gulf Cod	Southern Gulf Cod	Eastern Scotian Shelf	Comments
H28	Mortality rates of juveniles have increased due to non-retention mortality in groundfish gears. (Necessary to document bycatch rates and effort in the fisheries).	No estimates. Thought to be low, but catches by non-Canadian fleets unknown. **[3]**	Same as H27 **[B-3]**	no information, but information from elsewhere suggest post-selection mortality of cod to be low **[1? not an issue given drastically reduced effort?]**	minimal known bycatch, minimal effort of any kind in ESS groundfish **[2]**	Non-catch fishing mortality - Frechet.
1.3.2.3	Natural (?) Mortality					
H29	Natural mortality has been documented to have increased, but the mechanism is unknown.	No direct measure of M, but very high survey Z's and low level of documented deaths from fisheries. **[1]**	Not known. **[A-1]**	Yes, Sinclair 2001 **[will treat as a component of R/SSB]**	apparently **[1]**	
1.3.2.3.1	Predation					
H18	Predation by marine mammals has increased, and reduced cohort survivorship compared to historic rates. (Should be supported by both population and diet data.)	Consumption of cod by seals remained high as cod population declined, from which increased mortality is inferred. Combined with high survey Z's and low (?) offshore fishery removals, implies high M in offshore. Predation also occurs inshore. **[1]**	Seals consume large amounts of cod at ages 1 to 3. **[A-2]**	increase in natural mortality of cod consistent with increase in abundance of grey seals (Chouinard et al, 2002), diet information suggest that impacts should be much greater on juveniles but analysis show high adult M **[1 Swain et. al. 2000 CSAS Res Doc 2000/147]**	FMF SPA **[1]**	
H19	Predation by a specified other predator or suite of predators has increased, and reduced cohort survivorship compared to historic rates. (Should be supported by both population and diet data.)	No sugestion in literature. **[3]**	Not known. **[C-3]**	no evidence **[3]**	Ecopath data **[2]**	
1.3.2.3.2	Physical Envrionment/Habitat					

		Northern Cod	Northern Gulf Cod	Southern Gulf Cod	Eastern Scotian Shelf	Comments
1.3.2.3.3	Trophic Limitation (via Condition?)	For H20 to H38 (below): There is no indication of trophic limitation, as deduced from low condition. Data will be presented.				
H22	Competitors for juvenile food have increased their abundance and/or consumption of shared foods, reducing the cod food supply, allowing consequences in 20 and/or 21.	**[2]**	Denis Chabot ? **[B-2]**	no evidence **[1 not distinguishable from H11 re. pelagic fish]**	ecopath results? Forage species trends? **[1]**	Quantity and quality of food for larvae & young juveniles - FOC review of AZMP and other plankton data for trends in quantity and composition of plankton. Who applies trends to stock productivities was unspecified.
H24	Timing of food availability has changed such that annual cycle of feeding and growth are disrupted. (This would require documenting change in timing such as earlier or later spring bloom, and would be helped documenting some relationship of feeding or growth to the food items whose temporal availability has changed.)	**[3]**	Denis Chabot ? **[B-2]**	not studied, no information **[3]**	no idea **[3]**	Quantity and quality of food for larvae & young juveniles - FOC review of AZMP and other plankton data for trends in quantity and composition of plankton. Who applies trends to stock productivities was unspecified.
H37	The spatial distribution of prey has changed in ways such that even if amounts have not declined, availability to cod has declined.	**[3]**	Denis Chabot ? **[B-2]**	euphausid decline **[3]**	no idea **[2]**	Quantity and quality of food for larvae & young juveniles - FOC review of AZMP and other plankton data for trends in quantity and composition of plankton. Who applies trends to stock productivities was unspecified.

		Northern Cod	Northern Gulf Cod	Southern Gulf Cod	Eastern Scotian Shelf	Comments
H38	Condition factor has been reduced for some or all parts of the year, whether or not any changes in feeding conditions have been documented. (This would benefit from some demonstrated consequences of poorer condition on growth, survivorship, or fecundity.)	**[2]**	Denis Chabot Johanne Gauthier ? **[B-2]**	Condition is typically low in spring (Schwalme and Chouinard, 1999), Condition has been generally lower recently than in the previous period of low abundance (mid-1970's) Chouinard and Swain 2002) **[3]**	CF data exists **[1]**	
1.3.3	Size-selective Mortality					
H15&H23	H15 and H23. The intrinsic (genetic?) growth rates of individuals has been reduced, such that even with sufficient food, mortality factors at a constant rate over time result in greater mortality on the cohort. This is accentuated if mortality sources are size dependent.	Growth rates have not been reduced (relative to mid- to late 1980s). **[3]**	Growth has been reduced in parallel with stock abundance. There seems to be a better growth in the last 5 years. **[B-2]**	shown to have occurred for southern Gulf cod (Hanson and Chouinard 1992; Sinclair et al, 2002) **[3? intense size-selective mortality (Sinclair et. al. 2002 CJFAS) but unknown whether there has been a genetic response]**	**[3]**	

		Northern Cod	Northern Gulf Cod	Southern Gulf Cod	Eastern Scotian Shelf	Comments
H45	Intensive selective fishing has resulted in a population of cod with smaller quasi-terminal size, and corresponding consequences for m and fecundity. (Could be considered a special case of 44.).	Offshore: uncertain because fish do not survive to large size. Inshore: no evidence of reduced growth of quasi-terminal size. **[3]**	The fishery lands larger size at age fish than the surveys. For fish aged 3 and 4 this is linked with the minimal lanfing size of 42 cm, for larger fish, this may be linked with highgrading at sea in order to reach higher prices. Asside from handlines and longlines, most other gears (dominant) have a girth based selectivity (trawls, gillnets and traps). **[B-2]**	There was strong phenotypic selection against fast-growing fish in the 1980s and early 1990s. Not known whether this resulted in genetic selection, though recent lab expts suggest a very rapid genetic response to size selection is possible in fish, and the continued small length-at-age suggests that this may have occurred in sGSL cod. Consequences for energy allocation, relative fecundity and M are even more unclear and speculative. **[1? intense size-selective mortality demonstrated (Sinclair et.al. 2002 CJFAS) but unknown whether there has been a genetic response; consequences for M unknown; consequence for recruitment tested in H2]**	**[3]**	

		Northern Cod	Northern Gulf Cod	Southern Gulf Cod	Eastern Scotian Shelf	Comments
	Effects on Recruitment					
H12	Productivity of key foods for larvae has deteriorated leading to increased direct mortality due to starvation. (Which foods – both trends and cod diet data?)	Data from CPR and AZMP to be explored. (Pepin?)	Not known.	unknown	no info	Refered to FOC et al. for review of trends in zooplankton and larval fish diet
H13	Productivity of key foods for larvae has deteriorated, leading to reduced larval growth rate (have to document which foods from trends and diets). The reduced growth rate means size dependent mortality (any cause, but predation is an obvious one) at a constant rate over time will lead to greater mortality of the cohort.	Availability of relevant data to be checked (Pepin)	Not known.	unknown		Refered to FOC et al. for review of trends in zooplankton and larval fish diet
	Reproductive Biology					
H42	Body burdens of contaminants have increased, with possible (documentable?) detrimental effects on survivorship or fecundity.	Very little data. Levels much lower than would affect survival, egg formation.	Not Known.	Unknown,some baseline data available (Misra et al. 1989) but no recent sampling.		refered to P Yeats (BIO), Gobeil (Que), Fairchild (GFC) and Payne (Nfld?)
H43	Body burdens (or species composition) of parasites or disease organisms have increased, with possible (documentable?) detrimental effects on survivorship or fecundity.	Time-series of Lernaeocera only. No indication of major changes in infection rate.	Not known.	Decline in Anisakis simplex but increase in nematodes during 1988-1992. Levels in that period were higher than previous studies - link to grey seal abundance (Marcogliese 2001)		refered to , McClelland and McGladdery (GFC) and Brattey (Nfld)
	Adult and juvenile growth and production					

		Northern Cod	Northern Gulf Cod	Southern Gulf Cod	Eastern Scotian Shelf	Comments
H17	Some other physical oceanographic conditions for development are less favourable than they used to be. (We would have to document which oceanographic properties have changed – salinity, oxygen etc. It would be helpful but not essential to also have a mechanism that linked the property to successful development.).	No suggestions in literature.	Ultra violet B penetration ?	Unknown - no evidence to indicate this	Salinity and O2 data exist, no analysis, new advection indications (Petrie), juvenile have concern wrt slection bias in growth of partially selected ages	
	Juvenile growth and survival					
H26	Habitat quality for juveniles has been reduced, especially due to human activities (trawling). (Necessary to document what habitat features have been changed, and how widespread the changes are).	No evidence from this geographic area. Inference from studies elsewhere.	refered to Kulka and Anderson	Unknown	no info	refered to Kulka and Anderson

Fisheries and Oceans | Pêches et Océans

Maritimes Region

Annex 5

DFO Science

Stock Status Report A3-03(2003)

EASTERN SCOTIAN SHELF COD

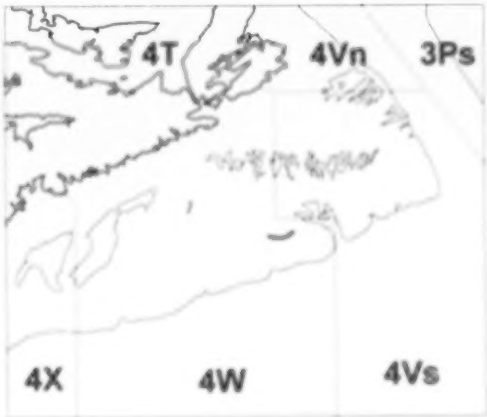
Background

The cod resource on the Eastern Scotian Shelf is a complex of spawning components including at least two major offshore groups (Western/Sable and Banquereau), smaller offshore groups (Middle Bank, Canso Bank) and a chain of smaller coastal spawning groups. The situation is complicated by the presence of both spring and fall spawning in several of the spawning components (Sable/Western offshore and various inshore areas).

Growth rates differ between 4Vs and 4W so that in the 1970's fish in 4Vs fish reached 68cm at age 7 while in 4W reached 72cm. In the mid-1980's growth declined in both areas and the average length at age 7 dropped to 59 and 54 cm respectively from 1985 to 1995.

The fishery for 4VsW cod was prosecuted primarily by foreign vessels until the extension of jurisdiction in 1977. Since that time, the Canadian offshore trawler fleet accounted for 70-75% of the landings and longliners most of the rest. Catches from 1958-79 were about 40-50% from 4Vs, however, as the stocks rebuilt in the early 1980s, the fishery shifted more to the east each year and 4Vs accounted for 60-80% of the landings from 1980-93.

The fishery was closed in September 1993 and has remained closed since then. Catches are limited to restricted bycatches in other fisheries and removals by the Sentinel program.



The most recent full assessment of this stock (DFO, 1998; Mohn *et al.* 1998) was in 1998 and was updated annually until 2002.

Summary

- The fishery has been under moratorium since 1993 and the total removals (bycatch and Sentinel program) have been less than 300 t per year since 1998.
- There are no indications that stock recovery is occuring or imminent.
- Since the moratorium, the spawning stock biomass has declined steadily in the absence of a fishery and is at or near its all-time low.
- Natural mortality on both adults and juveniles is extremely high.
- The size at age in the stock has been small but stable in recent years, providing little growth production. The fish condition has improved in the last two years although it has not translated into improved growth.
- Recruitment has been very low for more than a decade. The 1999 yearclass appears to be the largest since 1990 but is still substantially below the overall mean.

- Under the current productivity conditions (low recruitment, poor growth and high natural mortality) biomass projections indicate continuing decline for the medium term. A substantial reduction in natural mortality is required to even stabilize the projected biomass.
- The current stock size is far below any minimum biomass limits based on the stock-recruit history of this stock.

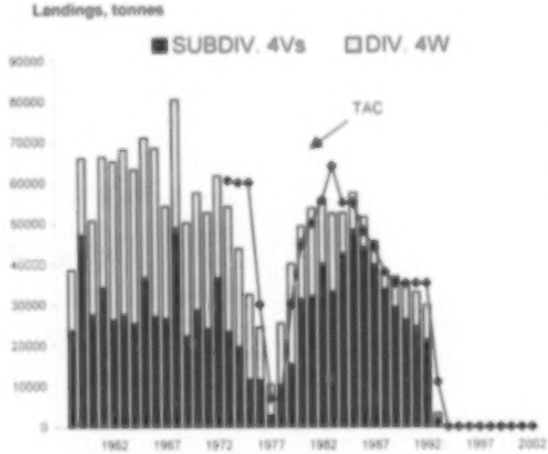
The Fishery

Landings (000's tonnes)

Year	58-69 Avg	70-79 Avg.	80-89 Avg.	90-97 Avg.	1998	1999	2000	2001	2002
TAC	None	36.4	49.0	14.6	0*	0*	0*	0*	0*
4Vs	31.1	18.4	37.4	9.4	0.11	0.21	0.09	0.09	0.03
4W	30.7	21.8	11.9	3.4	0.16	0.09	0.07	0.06	0.06
Total	[illegible]	40.2	49.3	12.7	0.27	0.30	0.16	0.15	0.08

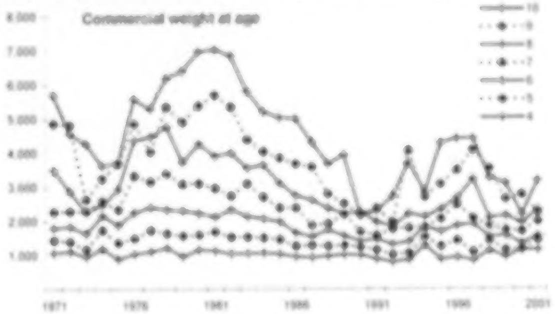
* bycatch only

The fishery has been limited to a restricted bycatch in other 4VsW fisheries (halibut, redfish and flounder) since September 1993. Current removals also include a Sentinel program which conducts a stratified longline survey and commercial index. Total catchs in the Sentinel program have been less than 30 t since 1999.



Estimation of the age composition of the catch since the moratorium has been hampered by a lack of commercial or observer samples. Given that there is no directed fishery, cod landings are small, scattered and unpredictable. The catches at age for 1998 to 2002 were constructed using all available samples in a single key for each year. While this is not ideal there is insufficient sampling to partition the age-length keys and the catches themselves are small.

As with the catch at age itself, the commercial mean weights at age are poorly estimated since the fishery moratorium in 1993. The weights had begun to increase slightly in the mid-1990's but have declined again at most ages and continue to be very low. Changes in the commercial weights at age are confounded with changes in the dominance of the gears catching the cod.



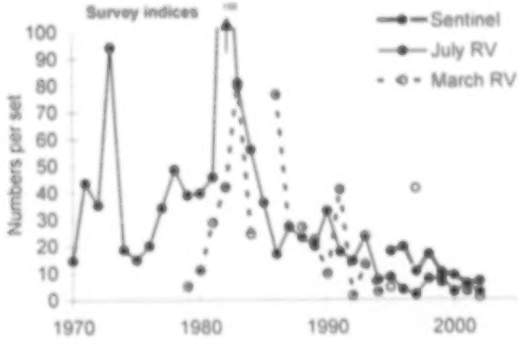
Prior to the moratorium, trawlers accounted for 50-70% of the landings while since 1993 they have accounted for 10-40%. Also the change from a directed fishery to a bycatch species has altered the distribution and timing of the little catch there has been.

Seal Predation Removals

The potential impact of seal predation is considered here using the model of Mohn and Bowen (1996). This is the same seal population growth and total consumption assumptions as in the previous assessment. There is no indication that the growth of the grey seal population has changed from the 11% per year used in the last assessment and thus the total food consumption by grey seals is estmated to now be about 310,000t. The proportion of cod in the seal diet has been re-estimated for recent years based on Quantitative Fatty Acid Signature Analysis (QFASA). The pattern of prey fatty acids can be thought of as a prey signature that is deposited within the blubber of marine mammals in a predictable way. Fatty acids stored in blubber represent the integration of feeding over periods of weeks to perhaps months depending on the rate and degree of lipid storage. This means that the diets determined from fatty acids should not be biased by where the samples are collected. Preliminary results indicate that capelin and sandlance are dominant prey in the diets. Cod is occurring at only trace levels on average (i.e., less than 1%) suggesting that the modelled proportion of cod in grey seal diets (2.5-4% estimated for the period 1993-1997 in the last assessment), based on faecal sample data from Sable Island, was too high for the population as a whole. A constant 1% cod in the seal diet since 1993 results in an estimate of 3100t of cod consumed by grey seals in 2002. The age composition of the seal diet is still based on the estimates obtained from analysis of fish otoliths and other hard parts in the seal diet in the last assessment. Ages 1 and 2 make up over 50% by weight (>90% by numbers) of cod in the seals diet although ages up to 8 are observed.

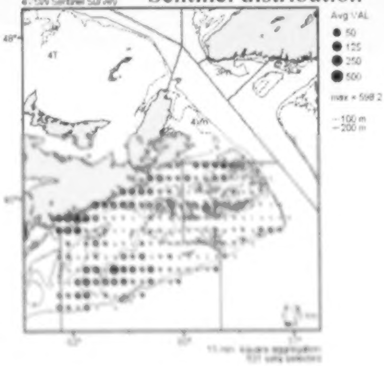
Indices of Abundance

There are now three useful indices of abundance for this stock. The July RV series runs from 1970 to 2002 without exception (recent results in Branton and Black, 2002) and the March RV series runs from 1979 to 2002 however several years were missed. The newest survey series is the 4VsW Sentinel Survey which has been conducted in Sept.-Oct. since 1995. All three surveys use stratified random survey designs although there are some differences in the stratification schemes employed. The stratified mean catch per set in all three surveys has declined since the late 1990's and are all at or near their lowest values.

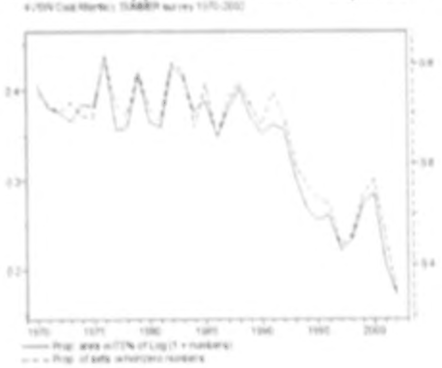


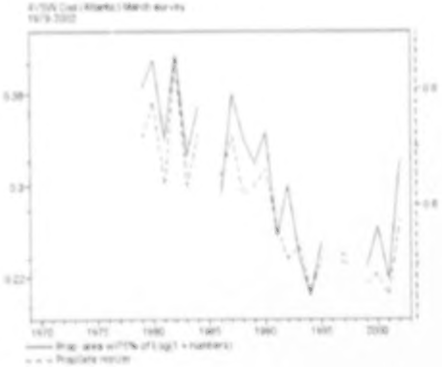
Spatial distribution of catches in all three surveys has become quite restricted. In addition to the concentration on Sable/Western Banks, the Sentinel surveys in September-October have consistently indicated an autumn aggregation in inshore strata, an area not sampled by the RV surveys.

Sentinel distribution

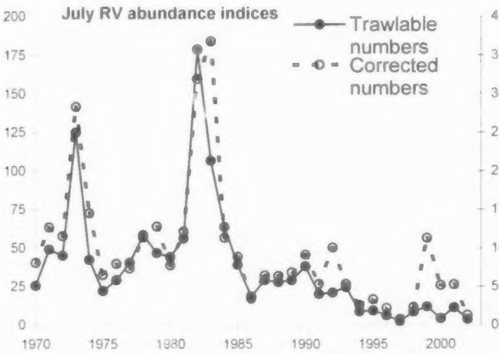


Indices of distribution in the two RV surveys have been at low values in recent years although the March distribution appears to have expanded in 2002.





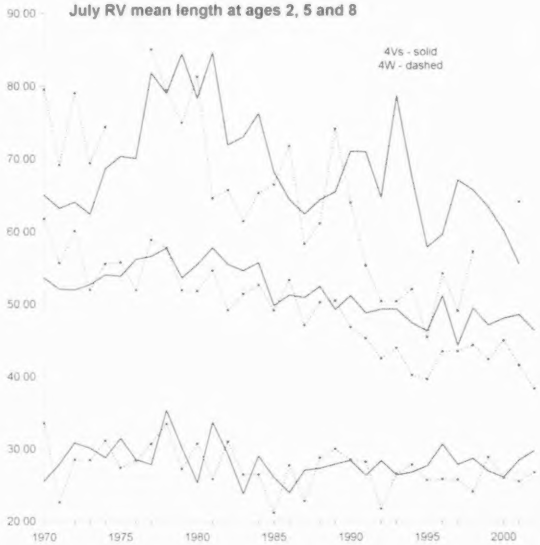
The trawl survey data are generally used only to produce relative indices of abundance beacause the catchability at length, even for a species as well studied as cod, is poorly known. A length-specific catchability correction is applied to the July survey data to account for the very low catchability of small individuals. The resulting corrected survey total numbers at age are a reasonable proxy for total population estimates. Comparison of trawlable (i.e. uncorrected for catchability) and corrected estimates shows that the corrected numbers (left axis) are about double the trawlable estimates (right axis).



Given the very low catch in recent years the ADAPT model used in the last assessment has not been used as the primary basis for this assessment. The corrected July survey data has been used in this assessment to estimate the important population parameters.

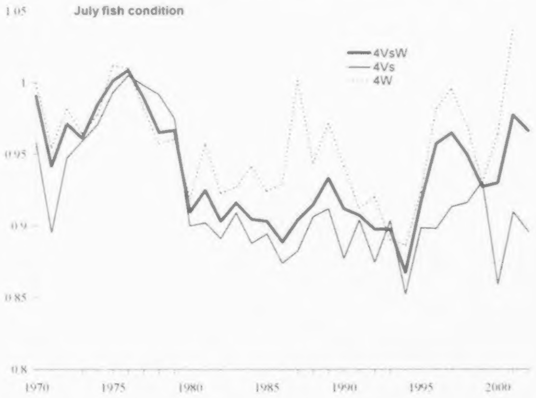
Growth and Maturity

The growth and condition of fish differs between 4Vs and 4W. The mean length at age has varied over years as well as differing between divisions. Mean lengths were higher in the period from the mid-70's to the mid-80's and have generally declined since then. The difference in mean length between 4Vs and 4W has increased in recent years with 4Vs fish larger than those in 4W.

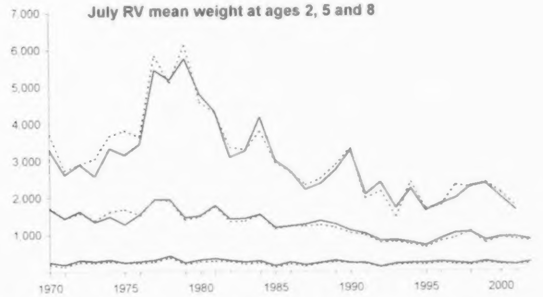


This must be interpreted carefully as it comes from very small sample sizes in 4Vs. The bulk of the survey catches are taken in 4W (>85% of numbers since 1999) and those sizes are more representative of the population as a whole.

Fish condition is estimated from survey length and total weight data. Overall condition has been improving in 4VsW since the mid-1990's, more so in 4W than 4Vs.



Mean weights at ages 2, 5 and 8 are compared between estimates based on the stratified survey length frequencies (solid) and catchability corrected length frequencies (dashed). The difference in mean weights between the methods is generally minor and the corrected weights are used subsequently for consistency with the corrected RV numbers. The mean weights of younger ages show little trend and are generally close to the long-term mean. Older ages (3+) are well below their long term means ranging between 60% and 80% of the averages.



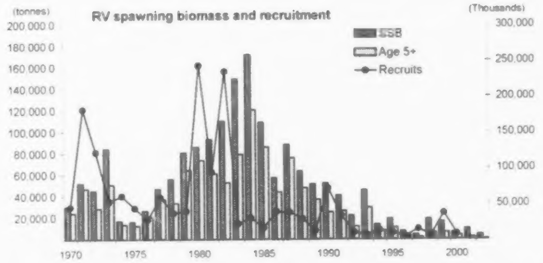
Maturity at length has increased for smaller fish since the 1970's. The changes in maturity at length are somewhat offset by reduced length at age but the age at 50% maturity has declined. In previous assessments the age 5+ biomass was used as a proxy for SSB but this is not appropriate when trends exist in both size at age and size at maturity. Based on the March survey data (near the spring spawning time) the maturity schedule has been revised to account for the changes noted.

Maturity schedule for 4VsW cod SSB

	Ages 0-2	Age 3	Age 4	Age 5+
prior to 1979	0.0	0.0	0.5	1.0
1979-1994	0.0	0.25	0.75	1.0
after 1994	0.0	0.5	1.0	1.0

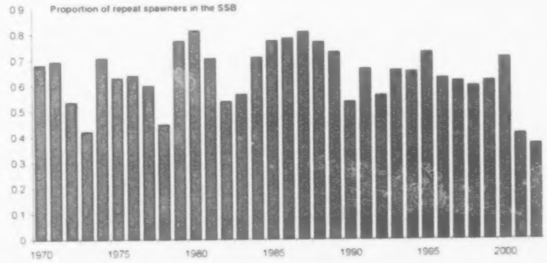
Resource Status

The SSB is calculated from the *q*-corrected survey numbers, the survey weights at age and the new maturity schedule. The effect of the change in maturity is seen by comparing the SSB to the age 5+ biomass. The corresponding age 2 recruitment estimates are from the corrected survey numbers. The biomass estimates for 2002 are at or near the lowest values for either SSB or 5+. The 1999 yearclass at age 2 appears to be the largest since 1990 but is still substantially below the overall mean.

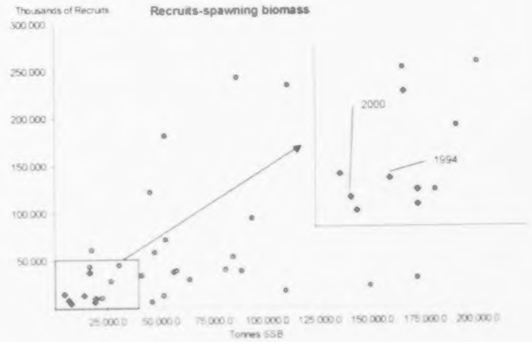


Recent work has shown that the reproductive potential of a stock is not fully described by the SSB. It is affected by the size, condition and reproductive history of the individuals in the spawning stock. Larger, older and repeat spawners make disproportionately larger contributions to production of viable eggs and larvae.

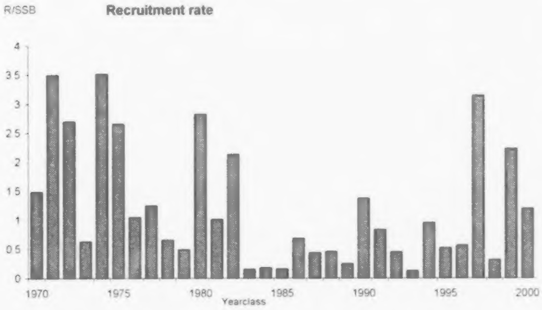
The proportion of the SSB made up of repeat spawners in the population is currently at the lowest proportion in the survey series.



The stock-recruit plot based on the q-corrected survey data indicates that all the recent yearclasses (1994 to 2000) are near the origin i.e. with both low SSB and low recruitment.

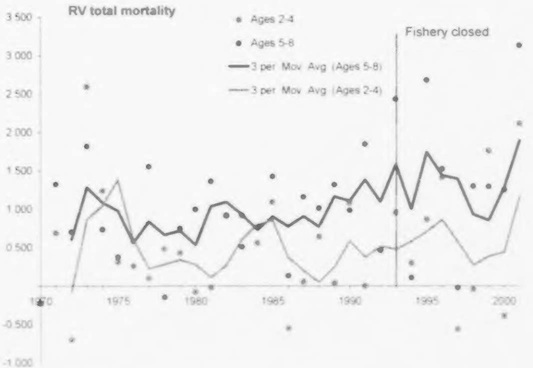


The recruitment rate (recruits/kg of spawners) shows that several recent yearclasses have been at or above the average. The 1999 yearclass has shown up strongly above average at ages 0 and 2. The estimate of the 1997 yearclass is questionable as it comes from a single strong estimate at age 2 and corresponds to a very low estimate of SSB i.e. a survey year effect. In spite of the various caveats, it seems likely that at least one or more recent yearclasses have been more productive (i.e. higher R/SSB) than those from 1983 to 1996.



Total Mortality

Estimates of total mortality (Z) between ages along cohorts were computed from the q-corrected survey population numbers. The means of two age groups (ages 2-4 and age 5-8) are representative of the trends in the younger and older parts of the stock. The Z's appear to have been increasing more or less continuously since the mid-1980's (ages 5-8) or late 1980's (ages 2-4). Although the younger group would not likely have been targetted in the fishery, the older group was the main part of the catch. In spite of that, neither age group shows a noticeable decrease in Z with the closure of the fishery in late 1993.

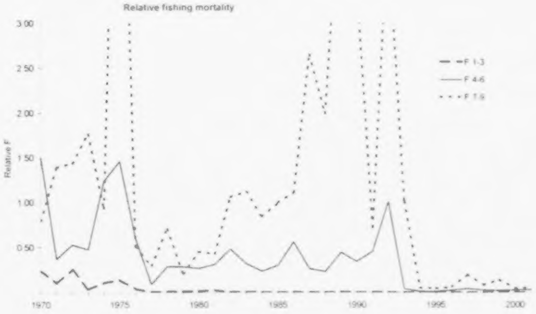


The Z since 1993 can be taken as an estimate of natural mortality (M) as the fishery catches have been negligible and indeed F is almost inestimable with SPA. The M (=Z) on the older ages has been about 1.0 and trending up. While the younger age group is lower, about 0.5, it is an underestimate due to changing catchability with age (see below) and is also trending upward.

The fact that the mean Z at younger ages averaged over years since the fishery was closed is higher than for older ages suggests that the correction applied is insuffficient for the younger ages.

Fishing Mortality

The relative fishing mortality is computed as the ratio of the catch numbers at age over the q-corrected July RV numbers at age. If the RV catchability corrections were completely accurate these mortality estimates would be absolute estimates of fishing mortality although still affected by the high variability in the RV estimates. Given the bias in the catchability corrections noted above the estimates for the youngest age group are likely overestimates of the actual F. There has been a steady increase in F over the period from 1977 to the closure of the fishery in 1993. Fishing mortality has been essentially zero since then.



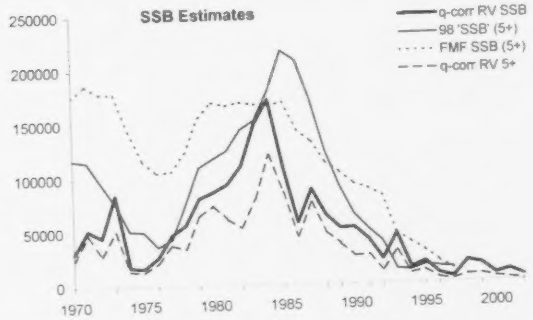
Surplus Production

The stock surplus production is the amount of biomass potentially available for fisheries yield in a given year. It is estimated as the change in biomass between two years plus the catch. Over the 10 years since the moratorium, the stock has lost on average more than 5000 t in biomass per year even without a fishery.

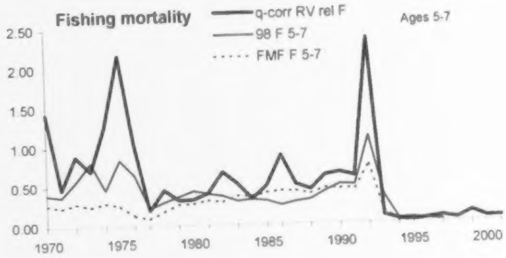
Under the current productivity conditions (low recruitment, poor growth and high natural mortality) biomass projections indicate continuing decline for the medium term. A substantial reduction in natural mortality is required to even stabilize the projected biomass. The current stock size is far below any minimum biomass limits based on the stock-recruit history of this stock.

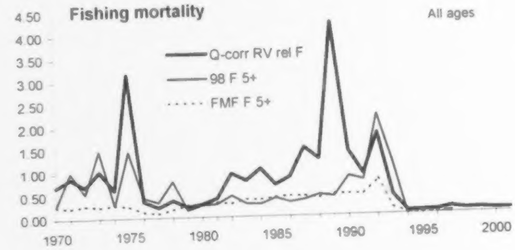
Comparison with other studies

In addition to the RV based estimates of population parameters presented in this assessment there are population reconstructions from other studies. The results of the current assessment are compared with those from the last assessment of this stock (Mohn *et al.* 1998) ('98') and a recently published analysis (Fu *et al.* 2001) (FMF). The impact of the new maturity schedule used in this assessment (*q*-corr RV) is included by showing the 5+ biomass as used in the earlier reconstructions. All of the analyses agree that the current SSB has declined to a small fraction of what it was in the 1980's. The FMF model suggests a much higher historical SSB than any of the other estimates but is consistent with the others since the mid-1980's



The fishing mortality estimates from the current assessment and the two earlier reconstructions are highly consistent for ages 5-7 through the time series. The closure of the fishery in 1993 has reduced the fishing mortality to nearly 0. When all ages are considered i.e. average 5+ F, there is a substantial difference between the estimates in the 1980's and early 1990's where the relative F from the q-corrected survey was indicating much higher mortality than either population reconstruction estimated.





Sources of Uncertainty

A variety of means of determining stock status show considerable agreement with respect to the current very poor status of this stock. There is greater uncertainty about the historical size of the stock although all estimates agree that the 1980's was an improvement over the mid-1970's.

The *q*-correction estimates used in this assessment incorporate various assumptions in both the underlying estimates and the meta-analysis. It appears that the implicit mortality assumptions in those *q*'s are still inadequate to fully correct the RV estimates for catchability at the younger ages (i.e. smaller sizes).

Predation mortality by grey seals on both juvenile and adult cod has been estimated based on a small amount of data and numerous assumptions. The resulting diet and consumption estimates are undoubtedly better than making no estimates of seal consumption but the specific estimates used here can be improved with more information.

Outlook

The outlook from the last Stock Status Report (DFO, 1998) for this stock, based on assessment of the stock (Mohn et al., 1998) was as follows:

> "The short-term prospects for this fishery remain dismal. The productivity of the stock is very low, there are several factors causing increased

> mortality overall as well as seal predation on the younger age groups. The spawning stock biomass, while not declining, has not rebuilt since the closure of the fishery. "

There are no indications that stock recovery is occuring or imminent. Moreover, it is obvious that the spawning stock biomass has declined steadily in the absence of a fishery and is at or near its all-time low. Natural mortality on both adults and juveniles is extremely high. The size at age in the stock has been stable at small sizes providing little growth production. The fish condition has improved in the last two years although it has not translated into improved growth. Recruitment has been very low for more than a decade. The 1999 yearclass appears to be the largest since 1990 but is still substantially below the overall mean.

For More Information

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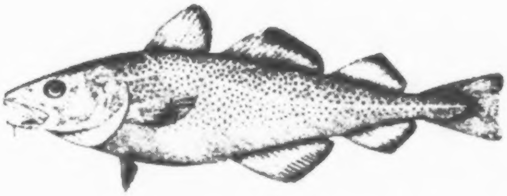


Northern (2J+3KL) Cod

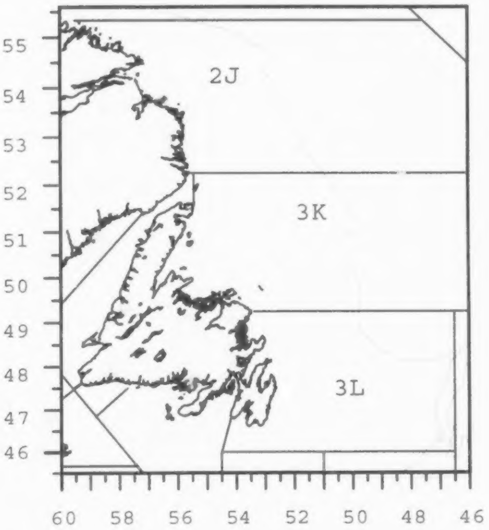
Background

The cod off southern Labrador and eastern Newfoundland have supported a commercial fishery since the 16th century. For the century prior to 1960 the catches were generally less than 300,000 t. With high catches in the late 1960s, mainly by non-Canadian fleets, the stock declined until the mid-1970s. After the extension of jurisdiction in 1977, the stock increased until the mid 1980s but then collapsed in late 1980s and early 1990s. A moratorium on commercial fishing was declared in July 1992. A TAC was reintroduced in 1998, but restricted to the inshore and to vessels less than 65 feet in length.

Historically many northern cod migrated from overwintering areas offshore to feeding areas inshore. From the 1960s until the moratorium, the fishery was prosecuted with large trawlers in the offshore, mainly in the winter and spring, and a fleet of smaller vessels in the inshore that deployed traps, gillnets and hook and line from late spring to autumn. There have always been some fish that have overwintered inshore. Following the collapse, a substantial portion of the remaining fish in the stock area appear to be inshore throughout the year.

Cod from this stock grow more slowly than those in warmer areas. An age 5 cod is presently about 50 cm (about 20 inches) long. Females mature at about age 5.

Cod in 2J3KL feed on a wide variety of food items. Capelin has historically been the major prey of adults.



Summary

- Status of the 2J+3KL cod stock was assessed based on data from research bottom-trawl surveys, sentinel surveys, prerecruit surveys, acoustic surveys in specific areas, tagging studies, a questionnaire completed by fish harvesters, catches from the commercial and recreational fisheries, and catch rates from the commercial fishery.

- The research bottom-trawl surveys in both autumn and spring indicate that the biomass of cod remains extremely low. The average trawlable biomass from autumn surveys during 1999-2002 is 28,000 t, which is about 2% of the average during the 1980s.

- Hydroacoustic estimates within two regions of the offshore (Hawke Saddle (2J) and the saddle along the 3K/3L boundary) were considered uncertain but

suggest a combined biomass of less than 20,000 t.

- Estimates from the autumn research bottom-trawl data indicate that mortality has been extremely high in the offshore since the moratorium and few fish survive beyond age 5.

- Indices of stock size from sentinel surveys, which are conducted with fixed gear in inshore waters, increased from 1995 to 1997-1998 and have since been declining.

- Catch rates from commercial logbooks declined from the opening in 1998 to the present.

- Catch rates in sentinel surveys and commercial fisheries have been consistently low in 2J and northern 3K. Since the fishery opened in 1998, catch rates have declined in both southern 3K and southern 3L, and have remained high only in northern 3L, most notably in southern Bonavista Bay and northern Trinity Bay. The opinions of fish harvesters, as recorded in responses to a written questionnaire sent to fish harvester committees throughout the stock area, are in general agreement with the above trends.

- Hydroacoustic surveys in January in Smith Sound (Trinity Bay) provided average indices of biomass that increased from 1999 to a peak of 26,000 t in 2001 and then declined to 20,000 t in 2003.

- Results of tagging experiments indicate a harvest rate close to 20% in the inshore in 2002 associated with a reported catch of 4,200 t. This harvest rate is in percent of exploitable biomass (approximately ages 4+), which was estimated to be 22,000 t in the inshore regions of 3KL. The exploitable biomass estimates increased during 1999-2001, but declined sharply in 2002. Most of the cod caught in southern 3L are thought to overwinter off southern Newfoundland (3Ps). The tagging studies provided evidence of natural mortality of 55% in 3K and 33% in 3L. These estimates are considered to be independent of unreported catch.

- A sequential population analysis (SPA) was conducted based on those cod in the inshore since the mid-1990s. The analysis incorporated catches during 1995-2002 and indices from the sentinel surveys and research vessel inshore strata. SPA estimates indicate that spawner biomass in the inshore increased from 1995 to 41,000 t in 1998, but has subsequently declined to only 14,000 t at the beginning of 2003. The estimate of 4+ biomass at the beginning of 2003 is about 30,000 t. Fishing mortality on older age classes has been increasing and is currently at approximately 35%, a level comparable to levels estimated during the stock collapse in the late 1980s and early 1990s.

- Both the SPA and a recruitment model indicate that the 1999 and 2000 year-classes are stronger than other year-classes since the mid-1990s, but are very weak compared to historic levels.

- The SPA indicates that the inshore spawner biomass has been decreasing since 1998 when the fishery reopened. Deterministic projections indicate that the stock will grow slightly in the short term as a consequence of the incoming recruits, but will decline thereafter if exploitation rates remain at current levels. Projections also indicate that even without fishing the spawner biomass will not grow during the next decade to the level reached in 1998, under the assumption that stock productivity does not increase above present levels.

- Consumption of cod by harp seals in 2000 is estimated from diet studies to have been about 37,000 t (95% confidence interval of 14,000 – 62,000 t). Most cod represented in such studies are small. Harp seals also prey on large cod by consuming only soft parts, and such predation has been frequently observed. Predation by hooded seals on cod has not been measured but is potentially large.
- The information on feeding by seals and trends in the harp seal population indicate that predation by seals is a factor contributing to the high total mortality of cod in the offshore and the high natural mortality of adult cod in the inshore.
- When the spawner biomass in the stock as a whole approaches 150,000 t, the available data will be reviewed to determine appropriate spawner biomass limit reference points in keeping with a precautionary approach. Based on historic data, it is anticipated that appropriate conservation limit reference levels will be set at levels greater than 300,000 t for the stock as a whole. Recovery of spawner biomass to this level is expected to take many years. While the stock remains below this level, there is a high likelihood that the productivity of the stock will remain impaired.

The Fishery

Catches of northern cod increased during the 1960s to a peak of over 800,000 t in 1968, declined steadily to a low of 140,000 t in 1978, recovered to about 240,000 t through much of the 1980s, and then declined rapidly in the early 1990s in advance of a moratorium on directed fishing in 1992 (Fig. 1).

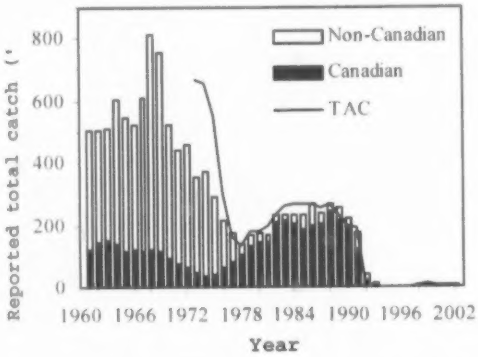


Figure 1. Reported catch and total allowable catch (TAC, thousands of tons).

Landings (thousand metric tons)

Year	62-76 Avg.	77-91 Avg.	1997	1998	1999	00/01	01/02	02/03
TAC	N/A	N/A	0	4	9	7	6	6
Can. Fixed	88	90	1	5	8	5	7	4
Can. Mobile	9	84	+	+	0	+	+	+
Others	405	38	0	0	+	+	+	+
Totals	502	212	1	5	8	5	7	4

+ Catch less than 500 t.

Catches during 1993-1997 came from by-catches, food/recreational fisheries, and DFO-industry sentinel surveys that started in 1995. A small index/commercial fishery limited to fixed gear deployed from small (<65 feet) vessels commenced in 1998. Catches from 1998 to 2002/2003 came from directed cod fisheries, by-catches, sentinel surveys and food/recreational fisheries.

The TAC of 5,600 t for 2002/2003 was to include all catches, including those from the food/recreational fishery. The **index fishery** was conducted on the basis of individual quotas. Participants were licenced to fish only in the Division of their home port, with an additional restriction within 3L to either north or south of Grates Point. Therefore, landings within each Division (or area within Division 3L) should reflect both the availability of fish and the number of licences in the area.

Participants in the index fishery were permitted to direct for cod with a limited quantity of either gillnets or linetrawls. Handlines could be fished in conjunction with either gear. Traps were permitted only to obtain fish for grow-out. Cod taken as by-catch in other fisheries were counted against individual quotas.

The **recreational fishery** was regulated by license and individuals were limited to 15 fish controlled by possession of tags. License holders were required to complete and return catch logs.

Reported landings were approximately 3,500 t from the index fishery, 100 t from the sentinel surveys, and 600 t from the food/recreational fishery, for a total of 4,200 t. It is known that in recent years there have been removals in excess of reported landings, but the magnitude of such removals is unknown. When all sources of landings were combined, gillnets contributed 66% by weight, linetrawls 1%, handlines 29% and traps 3%. Landings from 2J were < 1% by weight, increasing to 16% in 3K and 84% in 3L. The percentage of the total landings taken in 3K has declined steadily from 44% in 1998. The landings have become increasingly concentrated in space. In 2002, 36% was taken in Trinity Bay and an additional 13% was landed at the community of Bonavista just to the north of Trinity Bay.

No sampling of the recreational catch was carried out. Sampling of the commercial catch was insufficient in some cases and was augmented by sentinel survey data. The total catch at age comprised a range of ages, with ages 3-12 being important contributors and age 5 being most prominent. Ages 5-7 were most prominent in gillnets and ages 4-5 were most prominent in handlines.

Industry Perspective

A perspective on several aspects of the 2002 sentinel survey and index fishery is available from the responses to a questionnaire sent by the Fish, Food and Allied Workers Union (FFAW) to all Fish Harvester Committees in 2J3KL. Responses were received from 74 of 138 committees.

In response to whether commercial catch rates in 2002 were high, average or low compared with historical averages, 12% said high, 28% said average and 61% said low. All but seven responses from southern Labrador (2J) to northern Bonavista Bay (3L) were "low". The appearance of average catch rates for a period at two sites in southern Labrador represents the first indication in many years of the presence of adult cod in 2J. From inner Bonavista Bay to the western side of Trinity Bay the majority of the responses were "high". From inner Trinity Bay to the southern Avalon Peninsula the responses were "average" or "low", with responses of "low" coming from almost all sites in Conception Bay and the eastern Avalon Peninsula.

In response to whether commercial catch rates were higher, the same or lower than during the 2001 fishery, 12% said higher, 44% said they were the same, and 44% said lower.

In response to whether "signs" of small (up to 18 inches) fish were better, the same or worse than in 2001, 64% said better, 26% said the same and 10% said worse. Improving signs of small fish have been noted for several years. In response to whether the overall condition of cod caught during 2002 was good, average or poor, 60% said good and 40% said average. Good or average condition has been noted every year in these surveys.

In response to whether the trends seen in standardized sentinel and commercial catch rates are reflective of their perception of the overall trend in stock status, 72% said yes and 28% said no. Most of the "no" responses came from Bonavista Bay and Trinity Bay. It is understood that fish harvesters who said "no" meant that the actual status is better than reflected by those indices.

Resource Status

Stock structure

Since the mid-1990s, there has been a dichotomy between the inshore and the offshore. Cod in the offshore have been small and at very low density, whereas cod in the inshore have included larger sizes and have been found in relatively high densities in some times and places. Various observations, both historic and recent, and much of the genetic information, are consistent with the hypothesis that there are in the inshore populations that are distinct from those in the offshore. It is thought that these inshore populations have historically been small relative to the populations that migrated into the inshore from the offshore during spring/summer.

Tagging studies, conducted during the post-moratorium period while the overall stock size remains extremely low, indicate that the inshore of 3KL is currently inhabited by at least two groups of cod: (1) a northern resident coastal group that inhabits an area from western Trinity Bay northward to western Notre Dame Bay and (2) a migrant group that overwinters in inshore and offshore areas of 3Ps, moves into 3L during late spring and summer and returns to 3Ps during the autumn. The tagging also indicates considerable movement of cod among Trinity, Bonavista and Notre Dame Bays. It is not known if there is currently movement between the inshore and the offshore in 2J3KL. There has been only one reported offshore recapture of a cod tagged inshore after the mid-1990s, but of course there has been no directed offshore cod fishery during this period, so recaptures could come only from fisheries directed at other species.

Population Indices

The offshore biomass index values from the autumn **research bottom-trawl surveys** in 2J3KL have been very low for the last 10 years. The average trawlable biomass of 28,000 t during 1999-2002 is about 2% of the average in the 1980s (Fig. 2).

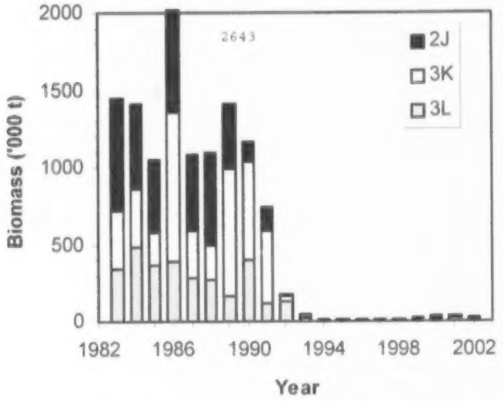


Figure 2. Biomass index from autumn bottom-trawl surveys in 1983-2002.

Slightly elevated presence of fish has been noted since about 1999 on the outer shelf near the 3K/3L boundary. Extension of the survey into the inshore since 1996 (with the exception of 1999) has resulted in some moderate catches in some years, particularly in the Trinity Bay to Bonavista Bay area.

The spawning stock biomass index computed from the autumn surveys has remained steady during the most recent four years at less than 2% of the average level of the 1980s.

The biomass index from the spring research bottom-trawl survey in 3L continues to be very low, at less than 1% of the average in the 1980s (Fig. 3).

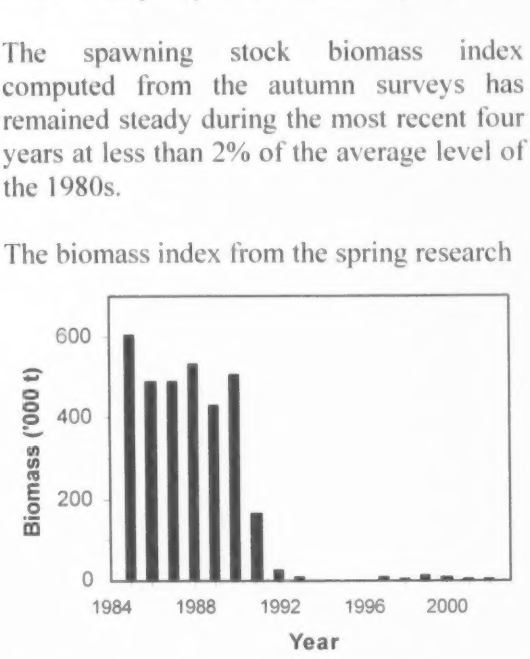


Figure 3. Biomass index from spring bottom-trawl surveys in 3L during 1985-2002.

Hydroacoustic studies have been conducted in Smith Sound in western Trinity Bay (3L) at various times since spring 1995. Surveys in January provided average indices of biomass that increased from 1999 to a peak of about 26,000 t in 2001 and then declined to 23,000 t in 2002 and 20,000 t in 2003.

Hydroacoustic studies were also conducted in two specific areas in the offshore. Biomass estimates from these studies are considered to be more uncertain than those from Smith Sound. Biomass estimates for Hawke Channel in 2J declined from 1994 to 1996 and varied between 2,000 and 7,000 t during 1998-2002. Biomass estimates from the saddle along the 3K/3L boundary declined from about 450,000 t in 1990 to less than 5,000 t in 1994. Biomass in the area was extremely low through the mid-1990s, but has increased somewhat in recent years (about 1,000 t in 2000-2001 and about 9,000 t in 2002). Most of the fish in both areas in recent years have been younger than age 6.

The **sentinel surveys** in 2J3KL were initiated in 1995 to provide catch rates and biological samples of cod in inshore waters. Catch rates have been relatively low since the start of the survey in 2J and in 3K north of White Bay. However, fish have existed in sufficient density to enable moderate to high catch rates in some times and places from White Bay to the southern boundary of the stock. Catch rates have declined since 1998 in 3K and southern 3L.

The sentinel survey data were standardized to remove site and seasonal effects and produce annual indices of total catch rate and catch rate at age for 3K and 3L combined. Gillnets and linetrawls were treated separately (Fig. 4). Gillnet catch rates increased from 1995 to 1998 but then declined to 2002. Linetrawl catch rates showed relatively little change from 1995 to 1996, increased in 1997, and then declined to 2002, with a small increase in 2001.

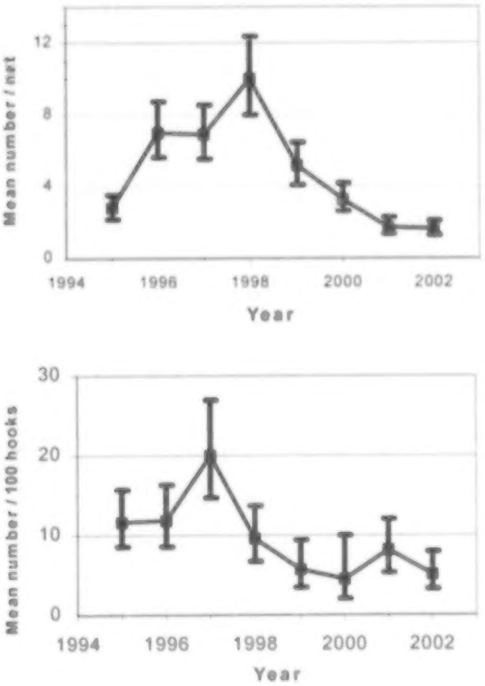


Figure 4. Standardized catch rates from sentinel surveys in 3KL; gillnets above and linetrawls below.

The sentinel survey catch rates at age indicated that the 1990 and 1992 year-classes were relatively strong and that subsequent year-classes are weaker. The catch rate at age 3 in the small mesh (3 ¼ inch) gillnets in 2002 (the 1999 year-class) were the highest in the time series, providing evidence of improved recruitment.

Commercial catch rates were calculated from catch and effort data recorded in logbooks maintained by commercial fishermen in the < 35 foot sector. The overall spatial pattern for gillnets, the predominant gear, has been similar among years (Fig. 5). Catch rates have been consistently low in 2J (not illustrated) and northern 3K. Since the fishery opened in 1998, catch rates have declined in both southern 3K and southern 3L, and have remained high only in northern 3L, most notably in southern Bonavista Bay and northern Trinity Bay. The area in which high catch rates can be obtained has declined considerably since 1998.

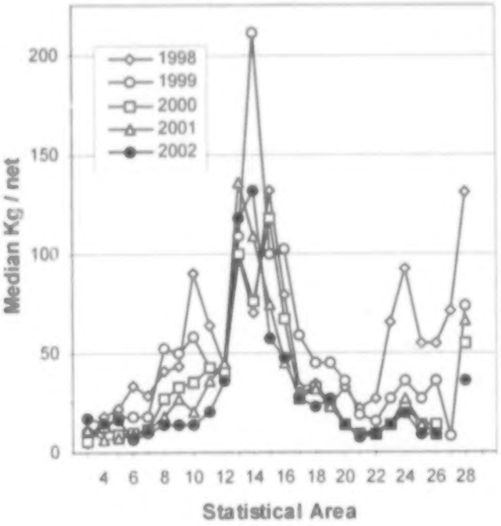


Figure 5. Median gillnet catch rates from the commercial fishery by statistical area from north to south, for the years 1998 - 2002. From north to south, area 2 starts at Cape Bauld, 6 at Cape St. John, 10 at Cape Freels, 14 at Cape Bonavista, 20 at Grates Point, 24 at Cape St. Francis and 27 at Cape Race.

The catch rates from logbooks were standardized to remove site and seasonal effects and to produce an annual estimate of total catch rate for 3K and 3L combined. Gillnet catch rates declined from 1998 to 2002 (Fig. 6). Data were insufficient to fit the same model to catch rates from linetrawl.

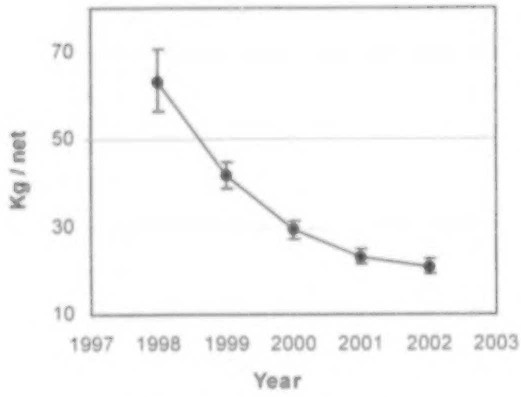


Figure 6. Standardized catch rates from the gillnet fisheries for cod by vessels < 35 feet in 3KL.

Inshore surveys of young cod (ages 0 and 1) have been conducted with beach seines in shallow coastal waters, which are thought to be the main nursery areas for northern cod. Surveys were conducted over a broad spatial scale in 1992-1997 and 2000 and on a finer spatial scale in 1995-1996 and 1998-2002. Catch rates of young cod were low in the mid-1990s but higher in the late 1990s.

Population Biology

The **proportion mature at age** increased among young female cod sampled during the autumn bottom-trawl surveys during the early 1990s and has fluctuated since (Fig. 7).

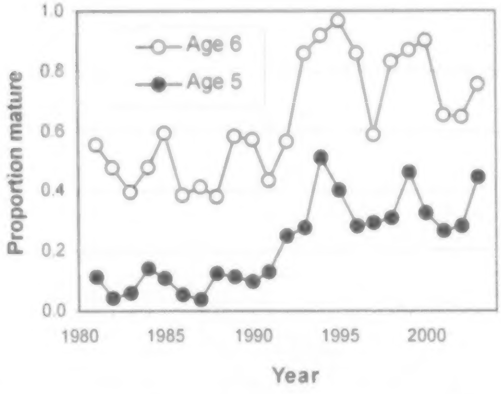


Figure 7. Percentage of females mature at ages 5 and 6 as predicted from modelling the maturity data.

For example, the proportion of age 6 cod that are mature increased from about 0.4-0.6 in the 1980s to greater than 0.6 since the early 1990s. Males generally mature about one year younger than females and show a similar trend over time.

Size-at-age of cod sampled during the autumn surveys declined during 1983-1985 and again in the early 1990s, especially in 2J (Fig. 8). Size-at-age has increased in recent years but is below peak values observed in the late 1970s. Much of the variability in growth is related to variability in water temperature.

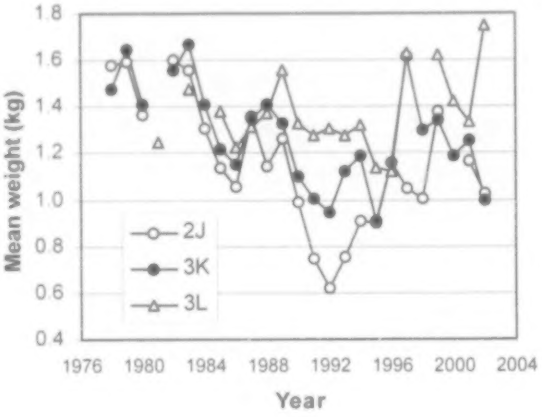


Figure 8. Mean weight (kg) at age 5 of cod sampled during autumn research surveys.

Condition of cod, as measured by both gutted body weight and liver weight relative to fish length, declined in the offshore during the early 1990s, especially in 2J. Since the mid-1990s, condition levels have been similar to those measured in the mid-1980s.

Population Analysis

Age specific **mortality** rates (proportion of population dying in a year) were calculated from catch rates during the autumn 2J3KL bottom-trawl survey. The rates for all ages rose to very high levels by the early 1990s, and remained extremely high for a few years after the start of the moratorium in 1992. The paucity of older fish (7+) in the survey since the early 1990s prevents estimating total mortality on these older ages. For younger ages (Fig. 9), mortality has remained very high (40-60% per year at age 4 and 60-80% per year at age 6).

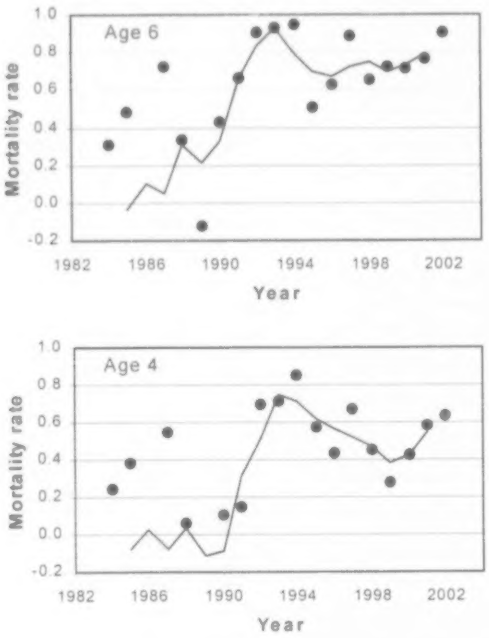


Figure 9. Age specific mortality calculated from catch per tow at age during the autumn bottom-trawl surveys in 2J3KL. As an example, in the age 4 panel, the value of 0.85 in 1994 is the mortality experienced by the 1990 year-class from age 3 in 1993 to age 4 in 1994. The line is a 3-year moving average. Data points less than –0.2, which occurred only before 1990, are not shown.

A **recruitment index** was derived from catch rates of juvenile (ages 0-3) cod during various studies that have been conducted since the early 1990s. Studies that are still contributing data are the stratified-random bottom-trawl surveys, both inshore and offshore, sentinel surveys (linetrawl, 5.5 inch gillnet and 3.25 inch gillnet) and beach seine surveys. The recruitment data from inshore and offshore were treated together because the inshore appears to be an important nursery area for cod spawning in both the inshore and the offshore.

These data were combined to produce a single index of relative year-class strength (Fig. 10). This index was low through much of the 1990s, but shows a pulse of better recruitment starting toward the end of the decade, with the 2000 year-class higher than any other in this short series. The 2001 and 2002 year-classes appear weak. The 2002 year-class is estimated with low precision.

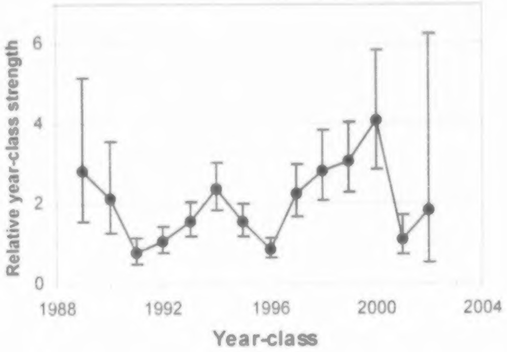


Figure 10. Standardized year-class strength.

It should be noted that strength of all of these year-classes is much lower than the strength of those that occurred during the 1980s. Moreover, the ability of the index to predict recruitment to the fishable population remains uncertain, particularly because it does not pick up the 1992 year-class that was relatively strong in sentinel and commercial catches.

A large-scale **tagging study** of adult (>45 cm) cod was initiated in spring 1997 in the 2J3KL and 3Ps cod stock areas. During 1997-2002 a total of about 78,000 cod were tagged and released and approximately 13,000 of these tagged cod have been reported as recaptured to date. A model has been developed which provides estimates of exploitation rate and exploitable biomass based on tag returns and reported catch. This model also provides estimates of cod body growth rates and the movement rates between stocks and subareas within stock boundaries.

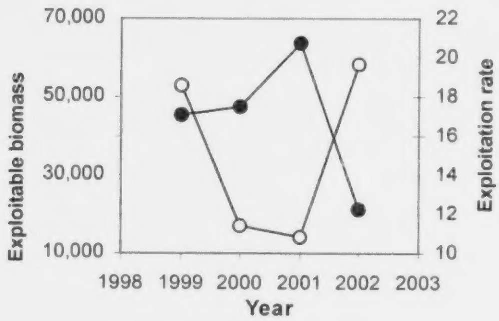


Figure 11. Tagging model estimates of exploitable biomass (closed symbols) and percentage exploitation rates (open symbols) for inshore 3KL.

Results of the tagging experiments (Fig. 11) indicate an exploitation rate close to 20% in the inshore in 2002 associated with a reported catch of 4,200 t. This harvest rate is in percent of exploitable biomass (approximately ages 4+), which was estimated to be 22,000 t in the inshore regions of 3KL. The exploitable biomass estimates increased during 1999-2001, but declined sharply in 2002. The tagging studies provided evidence of natural mortality of 55% in 3K and 33% in 3L. These estimates are considered to be independent of unreported catch.

Prior to the collapse of the 2J3KL cod stock, **sequential population analysis** (SPA) for the stock as a whole was the main tool used to estimate stock size and trends over time. This method was reintroduced in the current assessment and applied to those cod in the inshore since the mid-1990s. The analysis incorporated catches during 1995-2002 and indices from the sentinel surveys and research vessel inshore strata. SPA estimates indicate that spawner biomass in the inshore increased from 1995 to 41,000 t in 1998, but has subsequently declined to only 14,000 t at the beginning of 2003 (Fig. 12). The estimate of 4+ biomass at the beginning of 2003 is about 30,000 t. Fishing pressure on older age classes has been increasing and the exploitation rate is currently at approximately 35%, a level comparable to levels estimated during the stock collapse in the late 1980s and early 1990s.

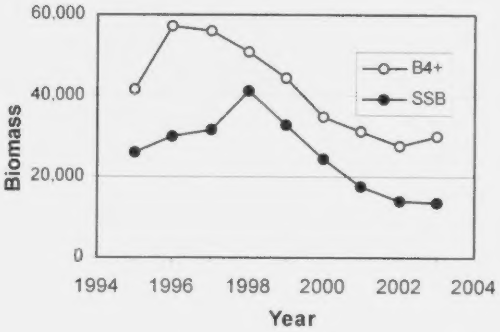


Figure 12. SPA estimates of spawner biomass and exploitable (4+) biomass for the inshore.

Both the SPA and a recruitment model indicate that the 1999 and 2000 year-classes are stronger than other year-classes since the mid-1990s, but are very weak compared to historic levels.

The SPA indicates that the inshore spawner biomass has been decreasing since 1998 when the fishery reopened. Deterministic projections indicate that the stock will grow slightly in the short term as a consequence of the incoming recruits, but will decline thereafter if exploitation rates remain at current levels. Projections also indicate that even without fishing the spawner biomass will not grow during the next decade to the level reached in 1998, under the assumption that stock productivity does not increase above present levels.

Under a **precautionary approach**, conservation limit reference points need to be defined to demarcate when the stock is considered to have impaired productivity and is thus in a situation in which serious harm has occurred. Northern cod productivity is impaired and serious harm has occurred. When the spawner biomass of the 2J3KL cod stock as a whole approaches 150,000 t, the available data will be reviewed with the objective of determining appropriate spawner biomass limit reference points in keeping with a precautionary approach. Based on historic data, it is anticipated that appropriate conservation limit reference levels will be set at levels greater than 300,000 t for the stock as a whole. Recovery of spawner biomass to this level is expected to take many years. While the stock remains below this level, there is a high likelihood that the productivity of the stock will remain impaired.

Multispecies Considerations

The quantity of cod consumed by **harp seals** during the period 1965-2000 was calculated using estimates of harp seal population numbers, energy requirements of individual seals, the average duration of seal occurrence within 2J3KL, the relative distribution of seals between inshore and offshore, and stomach contents of seals sampled in the inshore and offshore in winter and summer. An average diet was calculated for each of the four combinations of area (inshore and offshore) and season (winter and summer) using all stomach content data collected in 2J3KL during the years 1982 and 1986-1998. Uncertainty in the estimates of numbers at age, diets, residency time in 2J3KL and the proportion of seals in nearshore areas, were used to evaluate the possible range in consumption estimates. The only factor effecting annual changes in the estimates of prey consumption is the estimate of seal population numbers. Recent estimates of harp seal population size show that the population reached about 5 million in 1996 and has been fairly stable since.

Based on the average diets, it is calculated that harp seals consumed 37,000 t of cod in 2000 (with a 95% confidence interval of 14,000 – 62,000 t) (Fig. 13).

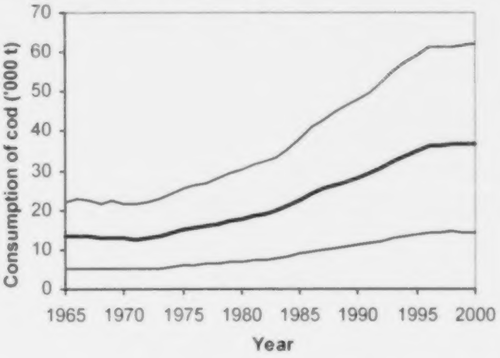


Figure 13. Consumption (with 95% confidence intervals) of cod by harp seals in 1965-2000, based on diets averaged over 1982 and 1986-1998.

Diet data from the inshore show that the per capita consumption of cod by harp seals has not declined with the collapse of the cod stock.

Numbers of cod at age consumed by harp seals from 1986 to 1998 were estimated from otoliths found in seal stomachs and total consumption estimates calculated from the seal consumption model. From 1986 to 1996 cod age 0 and 1 were the predominant age groups found in harp seal stomachs. In 1997 and 1998 older fish (ages 3-5) were the dominant age groups and fish as old as age 7 were found more frequently than in previous years. With this shift to older, larger cod the total number of fish consumed has decreased in recent years while the estimates of total biomass consumed have been relatively constant.

The estimates of cod consumption may be biased upwards because stomach content analysis relies on the presence and identification of hard parts (such as cod otoliths). Diet contributions from soft bodied animals or species with small otoliths may be missed or underrepresented.

The estimates of consumption of large cod by seals may also be biased downwards because incidences of belly-feeding will go undetected in diet studies. Belly-feeding is a mode of predation on fish which are usually too large to be consumed whole. The seal takes a bite from the belly of the fish, removing the liver and gut, but not consuming the muscle or hard parts. The weight of fish killed during an incident of belly feeding is much greater than the weight of fish consumed. Observations of belly-feeding were more frequent during 1998-2000 than in recent years, and occurred mainly in Notre Dame Bay and southern Bonavista Bay. Reports are still received, most notably from Smith Sound (Trinity Bay) where seal sightings have increased.

The trend in biomass of **capelin**, historically the major **prey** of cod in 2J3KL, has been uncertain since the late 1980s. Biomass estimates from hydroacoustic surveys in the offshore have been much lower since the early 1990s compared with the 1980s, but indices of capelin biomass from the inshore have not shown such extensive declines. Some studies of cod condition and feeding indicate that cod may not be faring well in certain seasons and areas, and that this is due to low availability of capelin. Other studies and observations do not suggest any concerns at present about cod growth or condition. Whatever the present circumstances, there remains concern that there may not be sufficient capelin to support a recovery of the cod stock, especially in the offshore and in the north.

Sources of uncertainty

The 2J+3KL cod stock is not recovering and the exact causes remain uncertain. While a number of factors are contributing to lack of recovery, it is uncertain whether or not one or more factors are dominant. Based on available data, it appears that seal predation could be the major factor but very little is known about harp seal diet in the offshore where cod mortality rates are particularly high. Unreported bycatch in the offshore by both domestic and foreign fisheries could also be a contributing factor. Cod mortality rates in the inshore are also high and there are many reports of predation by seals on adult cod. Harp seal diet data also show that cod are continuing to be eaten despite the small size of the stock. The evidence is thus stronger for the inshore that harp seals are playing a role in the high mortality of the cod and delaying recovery. However, unreported bycatches and illegal fishing could also be important.

The ecosystem in which the 2J+3KL cod stock is but one component has experienced dramatic changes since the 1980s. The relative importance of fishing, physical environment and biological interactions in causing and sustaining those changes is difficult to discern. There is considerable uncertainty regarding the extent to which climate variability and climate change may be influencing various aspects of cod well-being, particularly at the early life history stages. There is also much uncertainty about the biomass and availability of prey for cod at various stages of its growth, notably macrozooplankton during its larval and juvenile stages and capelin during its mid-life.

The potential for cod currently in the inshore to repopulate the offshore remains uncertain. Genetic studies using microsatellites have demonstrated a population substructure between most inshore and offshore areas. It has been suggested that this substruture indicates a low likelihood that inshore-spawning cod will contribute to offshore recovery. However, evidence of substructure may not preclude inshore-spawning cod playing a role in future offshore recovery. If fish currently in the inshore could recolonize the shelf, then allowing the inshore biomass to increase makes it more likely that inshore fish may move offshore.

It is unknown whether cod currently offshore undergo spring/summer feeding migrations to the inshore, and whether a rejuvenating population in the offshore would make use of the rich feeding opportunities that the inshore historically provided. However, there is a strong possibilty that offshore cod will continue to migrate inshore and that an inshore fishery could crop off a sizeable portion of any growth in the offshore. Many of the fish historically caught in the inshore were immature, so inshore removals may capture some offshore fish before they have a chance to spawn.

Outlook

The SPA indicates that the inshore spawner biomass has been decreasing since 1998 when the fishery reopened. Deterministic projections indicate that the stock will grow slightly in the short term as a consequence of the incoming recruits, but will decline thereafter if exploitation rates remain at current levels. Projections also indicate that even without fishing the spawner biomass will not grow during the next decade to the level reached in 1998, under the assumption that stock productivity does not increase above present levels.

The information on feeding by seals and trends in the harp seal population indicate that predation by seals is a factor contributing to the high total mortality of cod in the offshore and the high natural mortality of adult cod in the inshore.

Under a precautionary approach, conservation limit reference points need to be defined to demarcate when the stock is considered to have impaired productivity and is thus in a situation in which serious harm has occurred. Northern cod productivity is impaired and serious harm has occurred. When the spawner biomass of the 2J3KL cod stock as a whole approaches 150,000 t, the available data will be reviewed with the objective of determining appropriate spawner biomass limit reference points in keeping with a precautionary approach. Based on historic data, it is anticipated that appropriate conservation limit reference levels will be set at levels greater than 300,000 t for the stock as a whole. Recovery of spawner biomass to this level is expected to take many years. While the stock remains below this level, there is a high likelihood that the productivity of the stock will remain impaired.

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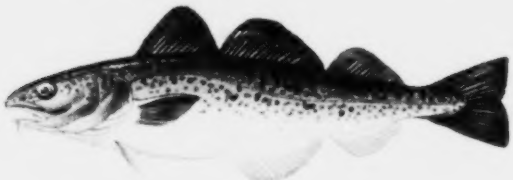


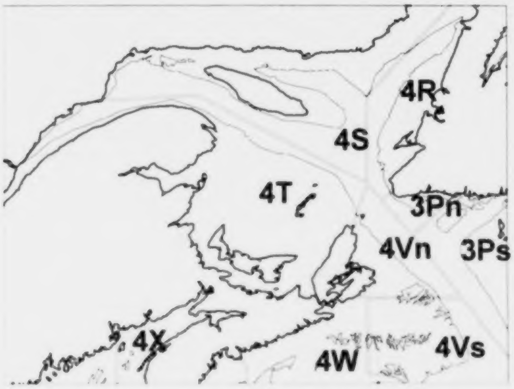
Cod in the Southern Gulf of St. Lawrence

Background

Southern Gulf of St. Lawrence cod are relatively long lived, and may reach ages of 20 or more when mortality is low. They begin to reach commercial size at age 4, and are fully available to the commercial fishery by age 8. They mature sexually at a size slightly below the commercial size of 41 cm (ages 4-5).

Southern Gulf cod are highly migratory. Spawning occurs in the Shediac Valley and around the Magdalen Islands from late April to early July. During the summer, the cod are widely distributed while they feed heavily on krill, shrimp, and small fish, primarily herring, Am. plaice, and capelin. The fall migration begins in late October and cod become concentrated off western Cape Breton in November as they move into 4Vn. The stock overwinters in 4Vn and northern 4Vs, along the edge of the Laurentian Channel. The return migration usually begins in mid-April, although this can be delayed by the late breakup of the winter ice. The management unit for this stock includes all of 4T and catches in 4Vn during November-April. In some years, catches in 4Vs in January-April are attributed to this stock

Southern Gulf cod have been exploited commercially since at least the 16th century. Landings varied between 20,000 - 40,000 t annually between 1917-1940, and then began to increase to a peak of over 100,000 t in 1958. The fishery was primarily prosecuted with hook and line until the late 1940s, when a ban on otter trawling was lifted. Landings remained relatively high in the 1960s and early 1970s, in the range of 60,000 t. TACs were first imposed in 1974, and these became restrictive as the stock declined in the mid-1970s. The stock recovered somewhat and landings returned to the 60,000 t range during the 1980s. During the 1980s, the fixed gear fishery declined drastically, and the fishery was mainly prosecuted by mobile gear until it was closed in September 1993, due to low abundance. A 3,000 t index fishery was allowed in 1998 and a TAC of 6,000 t was established in 1999. The fishery has been re-opened since 1999. Larger mesh sizes are in use in the mobile gear fishery since the re-opening. The management year for the fishery now runs from May 15 of the current year to May 14 of the following year.



Summary

- In 2002-2003, the TAC was 6,000 t. As of December 31, 2002, 5127 t had been landed.
- The abundance and spawning stock biomass of the stock are low and declining.
- All year-classes in the 1990s are estimated to be below average. Recent year-classes (1998-2000) are estimated to be the lowest on record since the early 1970s.
- Natural mortality remains higher than normal.
- With no fishing in 2003, the spawning stock biomass would be expected to decline.
- Rebuilding of spawning stock biomass over the next few years is unlikely, even with no fishery.
- Spawning stock biomass is estimated to be below the conservation limit reference point for this stock. There is a high likelihood that the productivity of a stock below the conservation limit has suffered serious harm.

February 2003

Canada

The Fishery

A TAC of 6,000 t was in place in 2002. This included an allowance of 700 t for sentinel surveys. Cod were caught in cod-directed fisheries and as by-catch in fisheries directed at other species, mainly flatfish. Directed fisheries for cod were closed until June. By-catch of cod in other fisheries were restricted to between 5 and 25% depending on the target species. As in previous years, a recreational fishery using hook and line gear was allowed with a daily bag limit of five groundfish.

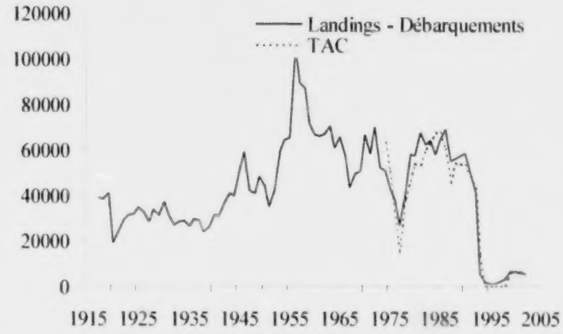
Landings (thousands of tonnes)

Year	1980-1989 Avg.	1990-1994 Avg.	1994-1999 Avg.	2000	2001	2002
Landings	61	31	3	6	6	5
TAC	59	26	2[1]	6[2]	6[2]	6[2]

1. Including the allowance of 3000 t for an index fishery in 1998.
2. TAC for May 15 to May 14 of the following year.

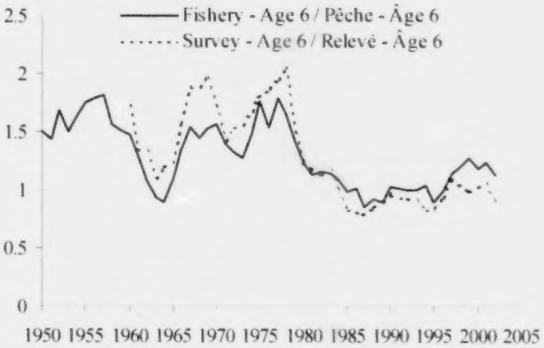
The total reported **landings** were 5,127 t in 2002. This is slightly lower than landings in the three previous years. Catches in the cod-directed and by-catch fisheries amounted to 4,326 t. Catch reporting in the commercial fishery is considered reliable. Sentinel surveys that are used to obtain additional indices of abundance of the stock caught 506 t. The recreational catches were estimated to be 295 t. As in recent years, the fishery in 2002 was concentrated close to shore in the Miscou Bank – Shediac Valley area, north shore of PEI, western shore of Cape Breton and the edge of the Laurentian Channel near 4Vn. A winter fishery was allowed on the over-wintering grounds in 4Vn during 2003, however only 16 t had been recorded at the end of February 2003.

Landings and TAC (t)



Ages six to eight were the most dominant age-groups in the 2002 landings but significant numbers of older fish were caught. Overall, the **average weights at age** of cod in the annual research vessel survey declined and remain low relative to the period before 1980. Weights at age in the fishery were also slightly lower than in 2001.

Average weight (kg)



Resource Status

The information used in this assessment included the annual research vessel survey (1971-2002), the landings data from 1917-2002, the commercial catch at age from 1971-2002, sentinel survey data from 1995-2002, the otter trawl catch rate data from 1982-1993, and the views of industry expressed in the annual telephone survey from 1996-2002.

Abundance Indices

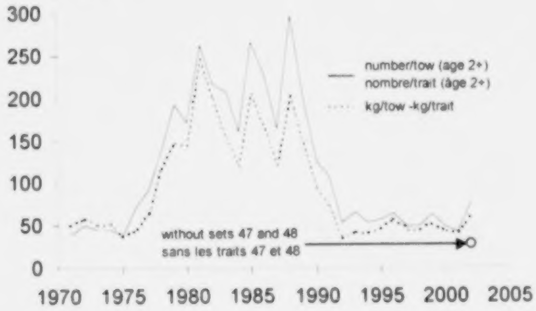
The **views of fishers** on the state of the resource were obtained primarily through a telephone survey of active cod fishers in 2002. Of 134 fishers interviewed, 37 % felt that the status of the stock was higher or much higher when compared to the previous year, while 30% considered the 2002 cod abundance to be lower or much lower than in the previous year. Although the opinion of fishers about stock abundance continues to be optimistic compared to surveys conducted when the fishery re-opened in the late 1990s, a higher percentage of them felt that there was either no increase or a decline in stock abundance.

The **annual research vessel (RV) survey** has been conducted in September since 1971. In 2002, 185 fishing sets were completed. All areas of the southern Gulf were covered. Due to two large sets in the survey, near the edge of the Laurentian Channel and separated by less than 6 nautical miles (sets 47 and 48), the index of abundance from the survey increased. These two catches accounted for 50% of the 2002 estimate. Even including these two sets, the mean catch rate in the 2002 survey is less than 40% of the average value for the 1980s.

The age composition of the two sets was composed primarily of cod of ages 4 to 8; the abundance of these year-classes was estimated to be lower in the previous surveys. When estimates of several year-classes increase simultaneously in a single survey, surveys in future years often indicate that the year of high catches was anomalous.

The abundance index used in the assessment included all sets in the 2002 survey but the impact of excluding the two large sets was examined.

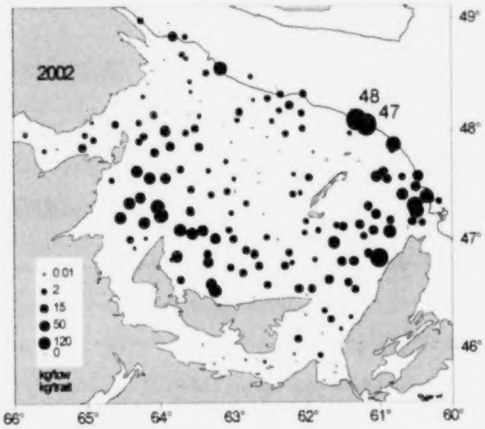
Survey Indices



The abundance of cod aged two and three years of age was near the lowest values observed in the survey in recent years. The results of the 2002 survey indicate that the stock continues to be at low abundance compared to the 1980s.

Survey mean weight per tow indicates that stock biomass has remained low since 1993.

Distribution of cod (kg) in the 2002 survey



With the exception of the two large sets, the larger catches during the 2002 survey tended to be distributed close to shore and in shallower waters, a distribution characteristic of periods of low abundance.

Highest concentrations were found in the Shediac Valley, the north coast of PEI and in the area between the Magdalen Islands and Cape Breton. The proportion of the survey biomass distribution found in the east was similar to that observed in 2001. The geographic range for the stock has contracted to the smallest area in the 32-year time series. This is consistent with the spatial pattern of the stock is at low abundance.

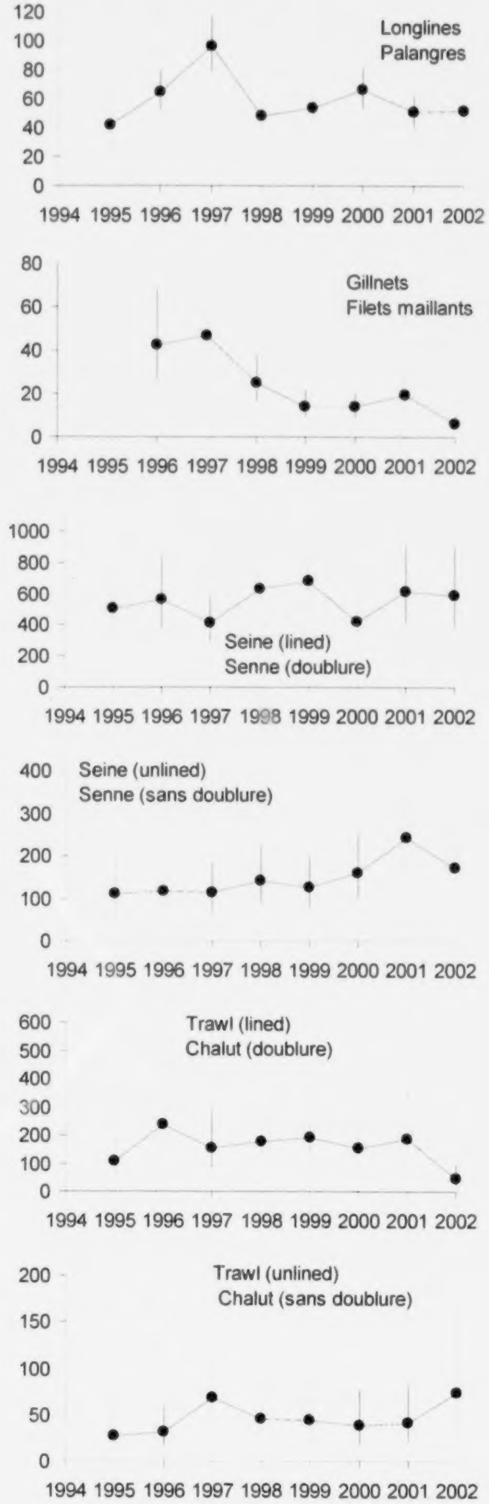
The **sentinel survey** program was continued in 2002. Thirty-seven vessels fishing with fixed and mobile gears in various areas of the southern Gulf were used to monitor cod abundance.

The catch rates in the sentinel surveys were compared to those of the research vessel index (weight/tow) and indicated similar trends.

Catch rates in the sentinel surveys suggest that there has not been a major change in population biomass since the mid-1990s. As in recent years, sentinel catch rates for fixed gears near PEI and for mobile gears in the Shediac Valley on the eastern shore of N.B. tended to be higher than in other areas. In a survey of opinions on stock abundance, sentinel fishers tended to be slightly optimistic about stock status.

An analysis of the strength of year-classes using the sentinel and survey indices suggested that recent year-classes (1998-2000) are poor.

Sentinel Catch Rate Indices



Natural Mortality

Previous work had indicated an increase in the **natural mortality** rate (M) of this cod stock. This would include unaccounted mortalities due to factors such as poor environmental conditions, predation, unreported catches and changes in life history characteristics.

Total mortality estimates from survey data have not declined despite population abundance indices and catches remaining relatively constant in recent years. This suggests that natural mortality has also remained relatively constant recently. Estimates of natural mortality from population analyses also suggested that M has not declined appreciably recently.

Consequently, the assumptions for M were the same used in previous assessments. M for all age groups was set at 0.2 from 1971 to 1985 and 0.4 from 1986 to 2002.

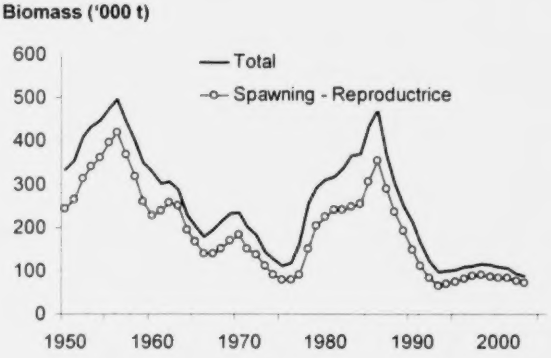
The contribution of each of the various potential causes to the recent high estimates of M is undetermined. Estimates of the predation of cod by grey and harp seals for this stock range from 19,000 to 39,000 t (all ages), depending on diet assumptions. The higher estimates were produced using diet compositions from outside the stock area.

Grey seals are estimated to consume more cod than harp seals in the southern Gulf. Although diet samples suggest that most cod consumed by seals appear to be less than 35 cm in length, diet analyses cannot account for cod that may be killed but not consumed totally (heads are not eaten). Changes in natural mortality estimates for cod are consistent with trends in grey seal abundance in the southern Gulf of St. Lawrence.

Spawning stock biomass was high in the 1950s, but declined throughout the 1960s and reached a minimum in the mid-1970s. There was a sharp increase in spawning biomass with the recruitment of strong year-classes (1974-75 1979-80), but then declined rapidly, reaching a low in 1993.

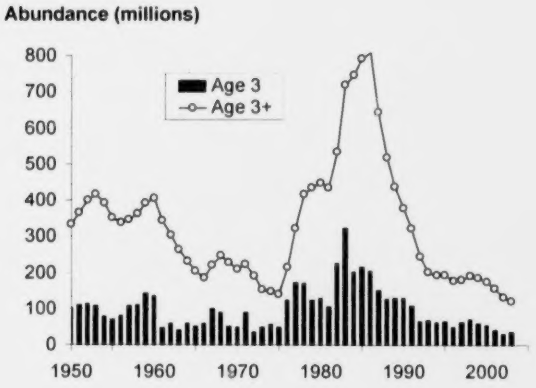
Spawning stock biomass has been low over the last five years, only 40% of the average spawning biomass of about 200,000 t.

Spawning stock biomass has declined over the last three years. The estimate of spawning stock biomass at the beginning of 2003 is 72,000 t. An analysis excluding the two large sets in the research vessel survey would result in similar trends but an estimate of spawning stock biomass that is about 10% lower in 2003.



Although the overall biomass has not increased, the biomass of older age-groups (8+) is estimated to be somewhat larger than in 1993. The closure of the fishery in 1993 resulted in higher survival for these age groups. However, because of the lower recruitment since the early 1990s, the biomass of younger age-groups (3-6) is estimated to be lower than in 1993.

The trend in total **abundance** is similar to that of spawning biomass. However, spawning biomass was lower in the 1980s than the 1950s due to lower weights at age. The continued decline in population abundance estimated in 2003 is caused by the low estimates of the 1998, 1999 and 2000 year-classes. The contribution of these year-classes to the spawning biomass in future years can be expected to be low.

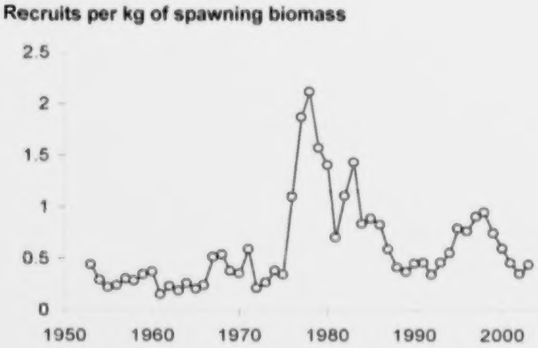


Recruitment of year-classes produced in the late 1980s and throughout the 1990s are significantly below the long–term average of about 100 million fish.

The 1993-1994 year-classes were previously estimated to be amongst the lowest for this stock since the early 1970s. The previous assessment indicated that the 1998 and 1999 year-classes were even poorer. This assessment indicates that the 1998-99 year-classes are still estimated to be the lowest on record. In addition, the 2000 year-class is estimated to be of similarly low abundance.

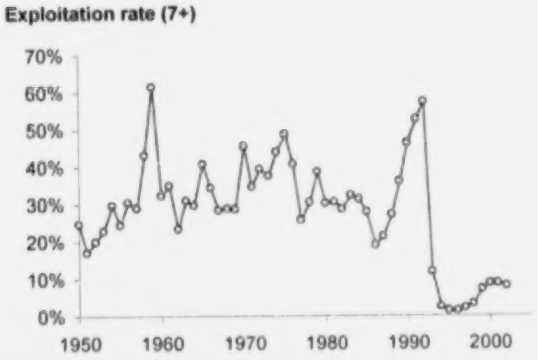
For each kg of spawning biomass, the production of recruits was higher in the period of the mid-1970s to the early 1980s. This promoted the rapid recovery of the stock observed in that period. Analyses have indicated that the high production of recruits per kg of biomass during that period may have resulted from the low abundance of pelagic fish species (herring and mackerel). Herring and mackerel feed on small preys including the early life stages of cod (eggs and larvae). Pelagic fish biomass (particularly mackerel) is expected to be very high over the next few years.

Despite improved recruitment per unit of biomass in the mid-1990s, no improvement in stock biomass was observed because of the high mortality rates and slower growth.



The **exploitation rate** increased from the early 1950s to the mid-1970s, with the exception of a high value in 1959. There was a slight decrease in 1977 and 1978 with the extension of fisheries jurisdiction. The exploitation rate increased again and averaged near 30% up to 1988. The exploitation rate then increased sharply and reached near 60% in 1992. Fishing effort was reduced markedly in 1993 with the closure of the directed fishery. Exploitation rates during the period of the moratorium have ranged between two and three percent. In 2002, the exploitation rate was estimated at about

8%, about the same as in the period 1999 to 2001.


Exploitation rate (7+)

Sources of Uncertainty

The estimate of natural mortality in recent years remains a source of **uncertainty** in the assessment. The predation by seals is considered to be a significant component of natural mortality and analyses suggest that changes in natural mortality are consistent with grey seal abundance trends. Recent analyses indicate that seal predation is higher than previously estimated, however, there is considerable uncertainty about seal diets in the southern Gulf. Diet analyses rely on the presence of hard parts from prey species in seal stomachs. Conclusions about diet composition would be affected if seals tend not to eat the heads of larger cod.

The estimate of the 2000 year-class (age 3 in 2003) is uncertain, as it is the first estimate of this year-class. However, this year-class will not contribute significantly to the fishery or the spawning biomass until 2004.

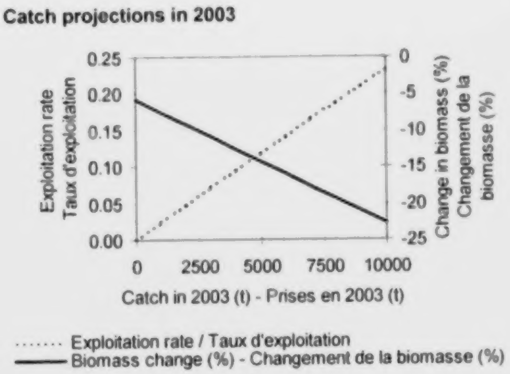
The increased proportion of larger fish in the population may cause many fishers to view the status of the stock more favorably. Their views also vary according to local abundance. The surveys indicate that cod were distributed closer to shore in recent years and that cod were rarely found in the central part of the survey area, contrary to the early 1980s.

Because of the low fishing mortalities, estimates of population abundance are particularly dependent upon indices of abundance.

Outlook

The productivity of the stock has been low for more than a decade because of poor growth and high natural mortality. Although the situation has improved marginally in terms of growth, the most recent incoming year-classes seem to be very weak. The estimates of the 1998, 1999 and 2000 year-classes are amongst the lowest on record.

Catch projections at various levels of catch in 2003 are provided. The estimates referred to below were made using the best available point estimates of stock size. For any catch in 2003, the associated exploitation rate is determined by reading up to the dotted line, then across to the left side. The percent change in spawning stock biomass can be determined by reading up to the solid line then across to the right side.


Catch projections in 2003

Given the low productivity, the spawning biomass is estimated to decline by about 6% if there is no catch in 2003. Maintaining the TAC at 6,000 t in 2003 would result in about a 16% decline in spawning biomass.

A projection over five years was also conducted assuming 3 scenarios. It is noted that predictions over this longer period can be expected to be more uncertain as there are currently no estimates for year-classes that would contribute significantly to the biomass at the end of the period. As well, it is assumed that a number of factors such as growth and natural mortality do not change.

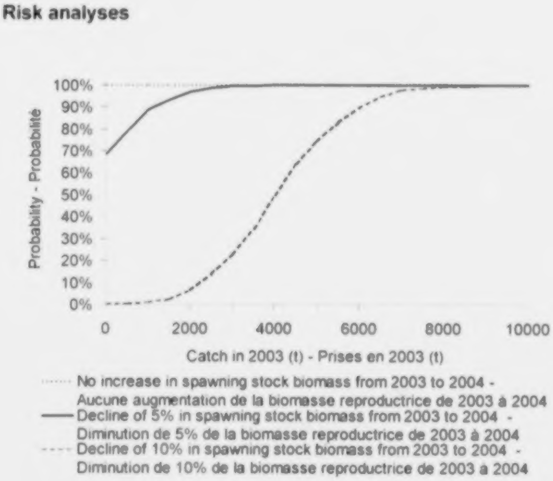
The three scenarios examined were as follows:

a) no fishery from 2003 to 2007
b) 2000-2002 exploitation rate (about 8%) from 2003-2007
c) quota of 6,000 t from 2003-2007

The results indicate that spawning stock biomass can be expected to decline even with no fishing over the next year because of low incoming year-classes. Spawning stock biomass would be slowly increasing at the end of the period. Maintaining the current exploitation rate or catch would result in a continued decline of the stock over the time period.

It is also possible to estimate the uncertainties regarding stock size and then use these in **risk analysis**. The risk analyses considered were: a) the probability that the 2004 spawning biomass would be less than the 2003 biomass, b) the probability that the 2003 spawning biomass would decline by 5% and c) the probability that the 2003 spawning biomass would decline by 10%.

There is a 100% probability that spawning biomass will decline during 2003 with no catch There is also a high probability (69%) of a 5% decline with no catch. The chance that the spawning biomass would decline by 10% if the TAC in 2003 was the same as in 1999-2002 (6000 t) is about 90%.



Risk analyses

These risk analyses include uncertainties of the population estimates but not those associated with natural mortality, weight at age and partial recruitment.

It should be noted that risk was calculated for the calendar year, whereas TACs for this stock are set for the period 15 May to 14 May.

At the low spawning biomass observed recently for this stock, there can be concerns that spawning stock biomass is sufficiently depressed such that the chance of obtaining good recruitment is greatly reduced. This could pose a risk of serious harm to the stock. Analyses for this stock indicated that the chance of obtaining good recruitment is reduced when spawning stock biomass is below about 80,000 t. The risk of being below this conservation limit reference point at the end of 2003 is 100%, even in the absence of fishing. There is a high likelihood that the productivity of a stock below the conservation limit has suffered serious harm.

The mid-term outlook (5 years) suggests that declines in spawning stock biomass are likely un-avoidable in the short-term, and rebuilding of spawning stock biomass is unlikely even with no fishery. The strength of recent year-classes and the level of natural mortality can affect this conclusion but a significant change in these parameters would be required to change this outlook.

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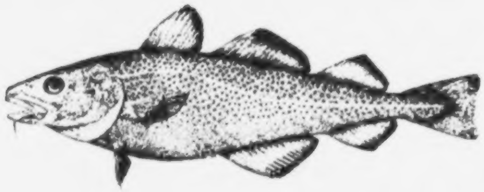

The Northern Gulf of St. Lawrence (3Pn, 4RS) cod in 2002

Background

The cod of the Northern Gulf of St. Lawrence (divisions 3Pn, 4RS) undertakes extensive annual migrations. In winter, it gathers off southwestern and southern Newfoundland at depths of more than 400 m (200 fathoms). In April and May, it moves towards the Port au Port Peninsula, on the West coast of Newfoundland (division 4R), where spawning starts. In 2002, a new zone was established in 4R to protect the spawning stock. It is a sector where any groundfish capture is prohibited between April 1st and June 15. During the summer, fish continues its migration and disperses towards the coastal zones, along the West coast of Newfoundland (division 4R) and towards the Middle and Lower North Shore of Quebec (division 4S). This migration towards the coasts is associated with warmer water and the presence of capelin, principal prey consumed by cod.

Based on the results of the many tagging experiments carried out, this stock is generally isolated from adjacent stocks (those of divisions 4TVn, 2J3KL and 3Ps). Stock can sometimes mix in the Northwest Gulf, (with stock of division 4TVn), in the Strait of Belle Isle, (with the 2J3KL stock), and especially in the area of the Burgeo Bank (with the 3Ps stock). A recent study evaluated that 75 % of cod present on the Burgeo Bank (3Psa and 3Psd) in winter would come from the Northern Gulf.

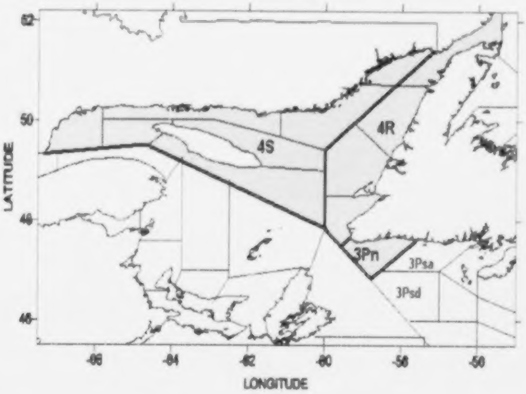

Figure 1: Cod stock management area in the Northern Gulf of St. Lawrence. For reference, fishery areas 3Psa and 3Psd are also indicated.

Landings (in thousands of tons)

Year	1977-1993	1994-1996	1997	1998	1999	2000	2001	2002[1]
TAC	70.4	0	6	3	7.5	7	7	7
Landings	70.2	0.3	4.8	3.3	6.9	6.8	6.7[2]	6.2[3]

[1] *Preliminary data*
[2] *Include 253 t for recreational fishery*
[3] *Include 34 t for recreational fishery*

Summary

- In 2002-2003, the TAC was 7 000 t. As of December 31, 2002, 6 246 t had been landed.
- The abundance and spawning stock biomass remain low. The stock abundance increased between 1994 and 1999 but has declined since.
- The recruitment estimates at age 3 have been declining since 1998 and recruitment is predicted to reach a historic low in 2003.
- Energetic condition and growth have improved in recent years, and fish now mature at older ages.

February 2003

- All three abundance indices based on research and sentinel trawl surveys increased from 1995 to 2000 but have declined since. The index from sentinel longlines increased from 1995 to 2001 but declined in 2002. This decline is most pronounced in southern 4R. The gillnet index appears to be stable.
- Cod are increasingly concentrated inshore in 4R and thus are more available to inshore fisheries. A portion of the stock may be becoming less available to research vessel and sentinel trawl surveys but is monitored by sentinel longlines.
- Natural mortality of adult cod remains high in this stock. Seal predation is a major factor contributing to this elevated mortality.
- Unaccounted fishing mortalities may have increased in recent years due to under-reporting in the recreational fishery and gillnet discards in the commercial fishery in 4R.
- Exploitation rate has been high since 1999.
- With no fishing, the stock is expected to increase marginally in 2003. With a 1 500 t fishery, stock abundance will likely not change. Catches of 7 000 t (the TAC since 2000) is estimated to result in a decline of about 12 % of the spawning stock biomass.
- Spawning stock biomass is estimated to be below the conservation limit reference points for this stock. There is a high likelihood that the productivity of stocks below the conservation limits has suffered serious harm.

Biological characteristics of the resource

The biological characteristics of the Northern Gulf cod varied over years, and certain changes occurred during the decline of the abundance of stock when the cold oceanographic conditions were unfavourable for the resource. Growth, condition, size and age at sexual maturity decreased in the middle of the 1980's and the beginning of the 1990's. These changes had a negative impact on egg production because a smaller fish, in bad condition at sexual maturity, is weaker and produces less eggs. On the other hand, the natural mortality rate may increase as a fish in bad condition has less chance to survive, particularly after the reproduction, when environmental conditions are unfavourable. However, an improvement of these biological parameters has been noted in recent years so that the assessment is more positive with regard to the biological characteristics of the stock.

The growth of cod increased during second half of the 1990's. Weight and size at age in the commercial fishery increased so that the actual values since 2000 are similar to those which were observed before the decline of the abundance, in early 1980's. Indeed, the mean weight of a 6-year-old cod in commercial fishery reached a minimum in 1992, then gradually increased since (Figure 2). The computed value of the mean weight for 2000 is the highest since 1984. Trends are similar for size and weight in the other year-classes. This increasing trend in size at age was also observed in the three trawl surveys carried out by the CCGS Alfred Needler, and the sentinel fisheries in July and October, as well as the sentinel fixed-gear fisheries (longlines and gillnet). Compared to 2001, 2002 mean weight of a 6-year-old cod are high for the gillnets and the survey of the CCGS Alfred Needler. Generally, weights at age from the surveys and the fishery have increased from 1990 to 1998 and varied afterwards without showing any trend.

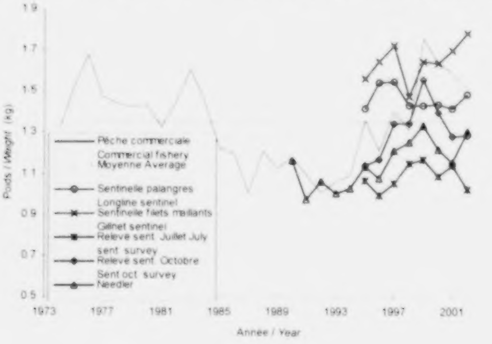

Figure 2. Mean weight of six-year-old cod caught in the commercial fishery, science surveys and fixed-gear sentinel fisheries. The dotted line is the commercial fishery average for the 1974-2002 period.

The size at which cod reaches sexual maturity was re-examined in 2002. Contrary to the former years, the conversion of the ogive of maturity for length to mature proportions of individuals at age was carried out using the mean lengths at age of scientific surveys (DFO and sentinel fisheries surveys) rather than the matrix derived from commercial fishery. This approach eliminates overestimation of the mean length at age of the young year-classes (3 and 4 years), which can affect commercial samples. This problem is mainly related to the 42 cm limit for commercial size and to the selectivity of commercial gears. This new calculation will more accurately reflect the proportion of mature individuals in the stock.

For 2002, a new ogive was calculated following a survey carried out in early May. The review of inter-annual variations of length at 50 % of maturity seems to indicate an increase of this value (46.8 cm) for 2002 compared to the last computed value in 1998, which was lesser than 40 cm. This length at 50% of maturity for 2002 would be comparable to the values identified in the 1980's.

The feeding of cod in 3Pn, 4RS is influenced by many factors such as season, depth, abundance of prey and the size of cod. The feeding of small cod is mainly composed of invertebrates like amphipods and shrimp (Figure 3). The proportion of fish in stomachs increases with the size of cod. Capelin is the dominant species consumed by cod less than 63 cm. Gadoids (mainly cod) and flatfish become important species consumed for cod above 53 cm.

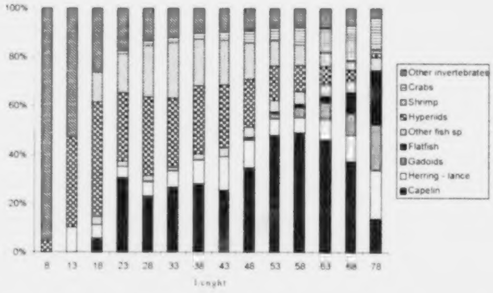

Figure 3. Cod feeding.

The condition of cod is a factor studied by a monitoring program whose aims is to determine the general health status of the Northern Gulf stock. Fish in good condition will have better chances of survival, particularly when environmental conditions are unfavourable. The condition of cod shows significant seasonal variations, with a maximum during the fall and a minimum during the spring. The energy reserves accumulated at the end of the fall are critical for cod and must be sufficient to pass the winter. Between 1983 and 1989, the condition of cod (evaluated in January) was good (Figure 4). Then, a significant reduction in the condition in January was observed between 1989 and 1994. A sentinel survey carried out in January 2002 revealed that condition level was good and comparable with levels recorded in the middle of the 1980's. Since 1990, the condition of cod is also evaluated in August, during the surveys of the CCGS Alfred Needler. The four measured indices – the Fulton index, the hepatosomatic index, the liver water content index and the muscle water content index – are considered good and indicate an increase for 2002.

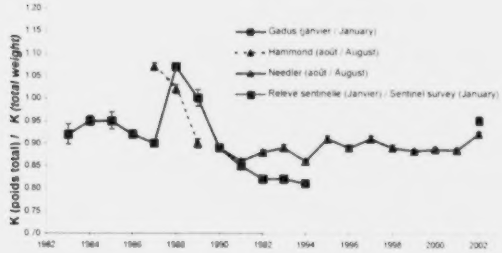

*Figure 4. Fulton condition index (mean ± standard error) for winter (*Gadus Atlantica, Sentinel 2002*) and summer research surveys (*NGCC *Alfred Needler) from 1983 to 2002.*

Description of fisheries

Cod landings in the Northern Gulf of St. Lawrence reached a maximum of more than 100 000 t in 1983 (Figure 5). Then, they regularly decreased until 1993. During the decline, boats using mobile gears captured their allocation, whereas those using fixed gears did not achieve it. Fishery was under moratorium from 1994 to 1996. A reduced fishery was authorized in 1997 with a TAC of 6 000 t and landings added up to 4 792 t. The TAC was brought back to 3 000 t for 1998 and 3 313 t were landed. In 1999, the TAC was set to 7 500 t and 6 890 t were landed. In 2000, the TAC was reduced to 7 000 t, and it has been maintained since. The landings of the fishery season (May 15 to May 14 of the following year) for 2000, 2001 and 2002 totalized 6 556, 7 150 and 6 246 t respectively.

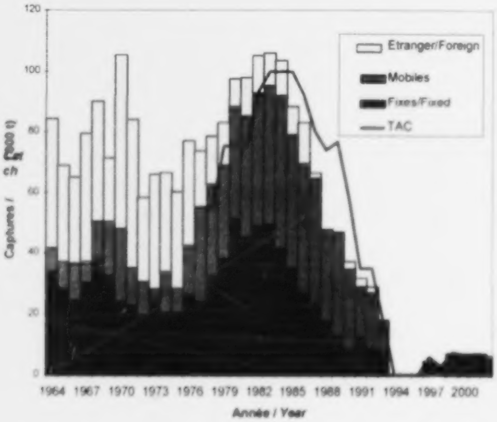

Figure 5. Landings and total allowable catches (TAC).

The profile of the commercial fishery has changed considerably since its reopening in 1997, as coastal directed fishing is restricted to fixed gears, such as longlines and gillnets. Fishing is carried out from small boats, and fishing effort is distributed over several monthly allocations. For example, a total of 2 000 hooks or 6 gillnets can be used by trip on the West coast of Newfoundland (4R and 3Pn), whereas a maximum of 25 gillnets for the West of Blanc Sablon and a maximum of 6 gillnets for the Blanc Sablon area can be used in the Lower North Shore of Quebec (4S).

Sentinel fisheries started in 1994 in order to develop a partnership between industry and the department of Fisheries and Oceans. Sentinel fisheries are carried out within a well defined framework and provide abundance indices of the resource. Three types of fisheries are carried out each year: sentinel gillnet fishery on Lower North Shore (division 4S) and on the West coast of Newfoundland (division 4R), sentinel longline fishery and sentinel otter-trawl fishery on the entire territory (3Pn, 4RS). All catches made within the framework of sentinel fisheries are accounted with total landings of commercial fishery. Sentinel fisheries had an allocation of 400 t in 2002, and the catches added up to 234 t.

To increase our knowledge of the mixture between the Northern Gulf stock and that of the Southern coast of Newfoundland, three surveys financed by the FFAW and directed by DFO were done with commercial trawlers in the area of mixing (3Psa and 3Psd), as well as in 3Pn and 4R in January, March and May 2002. The chemical analyses of the trace elements in the otoliths of cods collected during these surveys are in progress. Moreover, these surveys also allowed us to establish a new maturity ogive.

A recreational fishery pilot program was set up in 2001. At the time of last year assessment, the official data concerning fishing were not available. We had estimated that the landings could be of the extent of 886 t. Now, official data for 2001 and 2002 are available (253 and 34 t respectively). Thus, these new data are included in the current assessment.

At the time of the July allocation of 2002, concerns were made concerning the poor quality of landed fish caught by gillnets in 4R: they reached 22% by weight for categories B, C, and rejects. Moreover, it is likely that significant amounts of fish may have been discarded at sea.

Industry perception

For the fifth consecutive year the "Regroupment of the Lower North Shore Fishermen's Associations of Quebec" and the "Fish, Food and Allied Workers Union" of Newfoundland and Labrador have administered telephone surveys to fixed gear cod license holders in each NAFO zones. These organizations have been sponsors of the 4S and 3Pn, 4R Groundfish Sentinel Programs of the Northern Gulf of St. Lawrence (fixed gear sectors) respectively since the inception of the program in 1994. As in the past the surveys adopted a random sampling design. The current survey covered the 2002 fixed gear commercial fishing season with 50 fish harvesters being interviewed in 3Pn, 80 in 4R and 45 in 4S. The objective of the survey was to review various aspects of the fishery including fishermen demographics, biological information and trends in catch rates.

Results relating to fishermen demographics indicated that aspects of fishers experience in the fishery, average age and vessel length have remained very stable for all zones since the moratorium. For comparison of 2002 versus the 2001 season, respondents noted that cod size (overall length) and condition was the same or had increased. For 3Pn, more respondents noted a more positive result for both of these biological indicators compared to the other two zones. With respect to migration, the majority of the respondents in 4S and 4R noted that cod migration 'into' and 'out of' traditional areas occurred at the same time in 2002. However, a much greater percentage of 3Pn respondents noted that the fish migrated out of the gulf earlier and in fact the majority of these respondents commented on the fact that there was an excellent abundance of fish in 3Pn in August and September.

With respect to fishing depth, fishers have maintained activity on the same grounds with very little reported variation. With respect to spawning activity, a greater number of 4S compared to 4R and 3Pn respondents noted spawning activity based on the qualitative criteria stated in the question. This has been a result observed in the survey since its inception.

With respect to catch rates, the trend has typically been a decreasing one from north to south with the most optimistic perception in 3Pn. In 2002, all respondents indicated an improvement in catch rates compared to 2001. This result was most dramatic for 3Pn, where the average number was the highest in the time series. It is also worth reiterating that these values are much higher compared to the pre-moratorium period (i.e. 1992-93). Based on a retrospective index analysis, fishers in 4R and 4S have maintained a stable view of catch rates over the past three years while those in 3Pn are providing an increasingly more positive view of stock abundance (Figure 6).

Resource status

Abundance indices of catch rates from sentinel fixed-gear fisheries

Sentinel fixed-gear fisheries provide two abundance indices. The first index is derived from longline fisheries, and the second is calculated from gillnet fisheries. The catch and effort data was standardized with the use of a multiplicative model which allows to derive an index which reflects annual trends of abundance of cod since 1995.

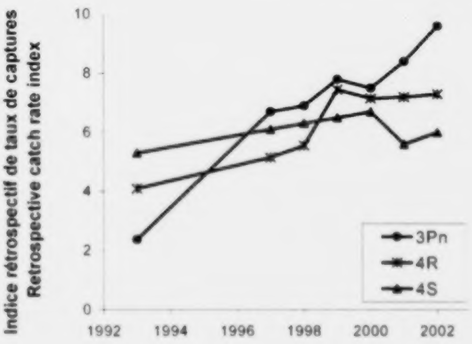

Figure 6. Retrospective catch rate index based on a questionnaire conducted by fishermen's associations.

The abundance index of sentinel gillnet fisheries in 4R and 4S shows very variable catch rates between years (Figure 7). The abundance index of sentinel longline fisheries in 3Pn, 4R and 4S shows an increase of the catch rates between 1995 and 2001, and a reduction for 2002. The good catch rates for sentinel longline fisheries since 1998 are due to the harvest of the 1993

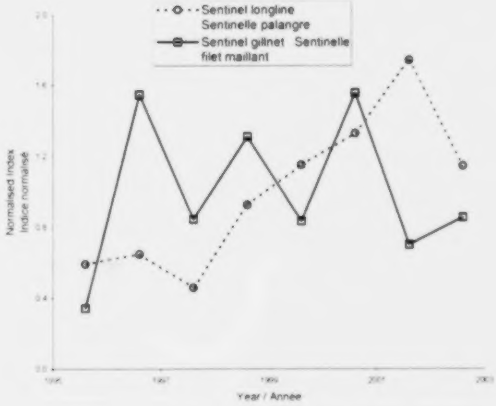

Figure 7. Normalised abundance indices derived from fixed gears.

year-class. In 2002, this year-class is 9-year-old and is less abundant, which may explain the decline of the abundance index for longline.

Trawl surveys

The sentinel mobile-gear fisheries program began in 1994 in the Northern Gulf of St. Lawrence, but it is only from 1995 that surveys have covered division 4S. The surveys are performed twice a year (July and October) by nine trawlers using a stratified random sampling protocol similar to that used by DFO with the CCGS Alfred Needler. The gears used were adjusted and standardized in 1997 with the addition of restrictor cables which maintain a constant trawl opening during fishing operations. The two surveys of 2002 followed an optimal station allocation plan (Gagnon, 1991) in order to minimize the variability of estimates.

The 1995-2000 data series from sentinel fisheries surveys of July suggests a slight upward trend of the abundance of stock for this period. A reduction is noted for the two surveys since 2001 (Figure 8). The two surveys indicate that the major part of the biomass is found in the zone 4R.

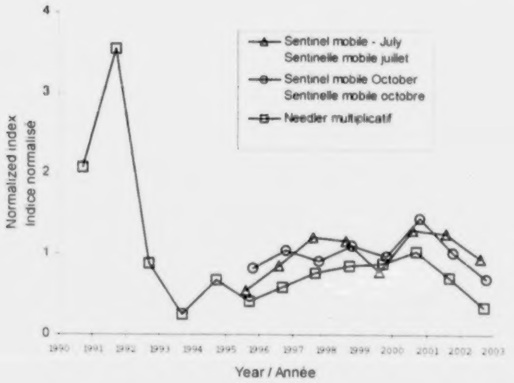

Figure 8. Normalised abundance indices derived from research surveys.

The summer survey carried out by the ship of the Ministry, the CCGS Alfred Needler, started in 1990 and was initially intended to assess shrimps populations and certain groundfish in the Gulf. Since 1991, adjustments have been carried out to increase coverage of the geographical territory frequented by cod; this was done by extending the surveys to the subdivision 3Pn and to depths ranging between 37 and 100 m (20 to 50 fathoms). The current assessment has corrected the situation by using a statistical model which allows to fill the missing annual data for these areas by using the trends observed in these zones during years of successful sampling.

The results from the DFO survey indicate that the abundance has increased from 1993 to 2000, but decreased in 2001 and in 2002. The index of 2002 is the second weaker of the 13-years series, the only lower value being that of 1993, right before the moratorium.

The estimates of minimum trawlable biomass of cod along the west coast of Newfoundland in shallow waters has increased for the July sentinel survey and for the DFO survey in August. This may reflect a displacement of cod to coastal waters. The proportion of minimum trawlable biomass in the 20-50 fathom stratum from the July sentinel survey follows closely the sentinel longline catch rates (Figure 9).

It is interesting to note that the three abundance indices based on mobile surveys reached a maximum in 2000, all declined in 2001 and continue to drop in 2002.

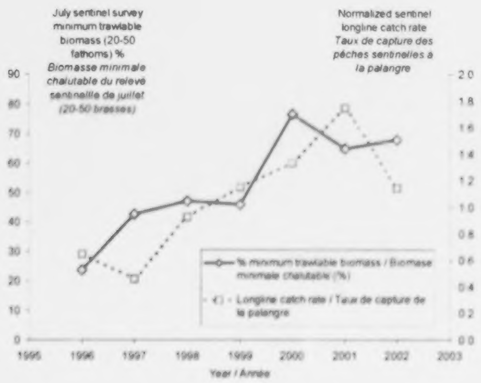

Figure 9. Comparison between the minimum trawlable biomass (%) in the 20 to 50 fathom depth strata from the July sentinel mobile survey and the sentinel longline catch rate normalised index.

Estimate of total population

The sequential population analyses (SPA) is an analytical model that allows to estimate population by year-class by taking into account natural mortality and fishing mortality as undergone by fish available to fishery. The analyses is based on the landings of 2000, 2001 and 2002 calendar years and were of 6 801, 6 950 and 6 439 t respectively. This analyses is also based on catches at the age estimated from commercial fishery and is calibrated with the indices of coastal sentinel fixed-gear fisheries, those of off-shore sentinel mobile-gear fisheries and those of the scientific survey made by the CCGS Alfred Needler.

To reflect the deterioration of environmental conditions, an increase in wastefull fishing practices and the intensification of predation by seals, it was decided during a zonal meeting held in the winter of 1999 to increase the coefficient of natural mortality (M) from 0.2 to 0.4 from 1986 for several cod stocks. Although the condition of the fish improved recently, the predation by seals is believed to remain important so that the coefficient of natural mortality has been kept to 0.4 for the entire period of 1986-2002 in order to take account of the combined effect of these factors.

Maturity ogives, or the proportion of fish sexually mature by size or year-class, are used to establish estimates, based on the results of the sequential population analyses, of spawning stock or spawning biomass. Results of SPA indicate that the abundance of 3-year-old and over individuals dropped from 559 million in 1980 to 56 million in 1994, before increasing slowly to reach 85 million in 1999. Thereafter, total population decreased to reach 51 million of individuals in early 2003. The abundance of the spawning stock decreased from 223 million in 1982 to 11 million in 1994. It increased to 23 million of individuals at the beginning of 2003. The exploitation rate on 7 to 10 year-old cod from SPA is stable and around 20 % since 1999 (Figure 10).

Population numbers were converted to biomass using mean weights at age from the commercial fishery calculated

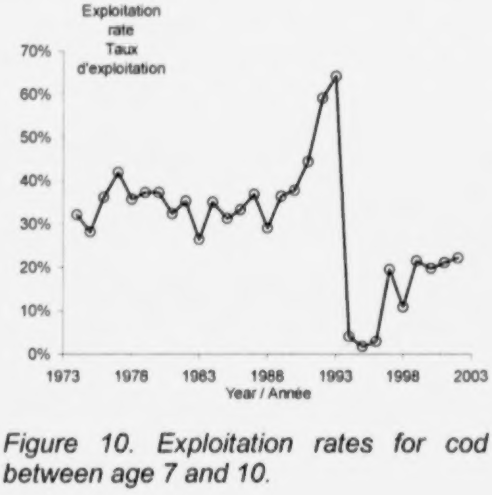

Figure 10. Exploitation rates for cod between age 7 and 10.

annually. The total biomass, for fish 3 years and older, passed from 604 000 t in 1983 to 36 000 t in 1994 (Figure 11). It increased to 62,000 t at the beginning of 2003. The spawning biomass decreased from 379 000 t in 1983 to 13 000 t in 1994, to increase thereafter to 39 000 t at the beginning of 2003.

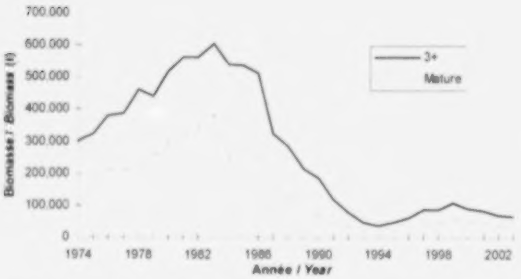

Figure 11. Estimated 3+ biomass and mature biomass.

Estimates for stock abundance and biomass for January 1st, 2003 were based on a mean recruitment (3-year-old fish) of mean weights at age and estimated maturity ogives for the last three years (2000 to 2002). Fishing mortality for the fully recruited individuals would have been of 22% (F=0.31) in 2002.

There have been no major signs of recruitment recovery since 12 years (Figure 12); commercial catches in the last four years have been sustained by the substantial 1993 year-class alone, which was produced prior to the application of the moratorium. Recruitment at age 3 has declined from 32 million individuals in 1998 to a historical minimum predicted at 10 million individuals in 2003.

Sources of uncertainty

The issue of the migration of Northern Gulf cod into fishing area 3Ps has been frequently discussed in the past. To avoid the capture of these cod during the winter fishery in the western area 3Ps, a portion of the Burgeo Bank (3Psd) has been closed to cod fishery from November 15 to April 15 since 1999. This area is only part of the area in which cod from the Northern Gulf stock (3Pn, 4RS) mix with 3Ps cod. Several research projects were carried out in recent years in order to better describe the extent of mixing (tagging, seasonal evolution of maturities, microchemistry of otoliths). A specific workshop on this issue was held in October 2000 (Chouinard, 2000). The conclusion of this workshop was that a good portion of cod captured during winter in areas 3Psa and 3Psd were from the Northern Gulf stock. As recommended by the workshop, in this assessment we have added 75% of the catches made from November to April in 3Psa and 3Psd to the catches of 3Pn, 4RS, which assumes that these catches are from the Northern Gulf. The inclusion of these landings have little impact as the estimated stock size increases by only 5% according to the sequential population estimate, compared to analyses that do not include them.

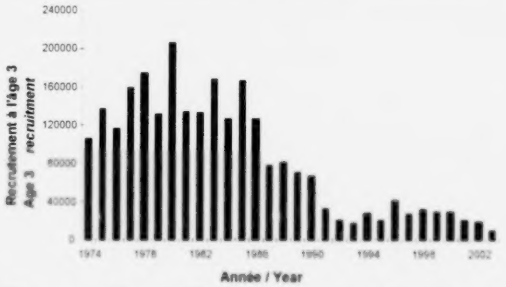

Figure 12. Estimated recruitment at age 3.

Results from the groundfish survey aboard the CCGS Alfred Needler in 2002 were reviewed in detail because there were a larger than usual number of unsuccessful tows in 2002, and most of them occurred in the earlier part of the survey. The larger amount of cod found in strata 20 to 100 fathoms is comparable to past surveys. Moreover, no tear ups occurred in the 20 to 50 fathom strata in 2002, where most of the cod were concentrated. Also, the pattern of residuals in the SPA suggests that the 2002 point from this survey were not highly influential on conclusions about stock status. Nonetheless, there remains uncertainty about the performance of the gear during that particular survey, which will be investigated further.

Adult mortality from natural causes is very high for this stock. Although causes of this elevated mortality are not fully known, estimates of cod consumed or otherwise killed by seals are high enough that such mortality contributed to the lack of recovery in this stock as well as for other stocks. The seal diet data indicate that the consumption is primarily of juvenile cod. However, stomach contents data underestimate the consumption of adult cod, because it has been observed that seals tend not eat the hard parts of large cod.

Unaccounted fishing mortalities may have increased in recent years for two reasons. First there may have been under-reporting in the recreational fishery. Second a new grading system put in place in 1999 in the gillnet fishery may have resulted in increased discarding.

In recent assessments, some tagging studies suggested exploitation rates were lower than indicated by other information sources. New analyses were able to largely reconcile results from the tagging with other indicators in this assessment. However, additional work on the tagging database and analytical methods can reduce further the uncertainty associated with the tagging studies.

Tagging and returns of tags

Since 1995, sentinel fishermen tagged more than 57 000 cod in the Northern Gulf of St. Lawrence. Until now, only 2 600 tags have been returned, which gave a low rate of return of 5%.

In 2000, following a recommendation of the FRCC to conduct more research in order to clarify this situation, sentinel fisheries and DFO initiated some experimental tagging programs with high value rewards (100$/returned tag) mixed with usual reward tags. These experiments with high value rewards have provided estimates of exploitation rate that are two to three times higher than those based on the rate of return for traditional tags.

Two analyses concerning tag returns were conducted during the 2003 assessment. One analysis estimated an exploitation level of 8 % while the other gave an estimate of 7 %. These estimates are similar to those obtained (9 %) for recent years through the use of the sequential population analysis for cod of equivalent size (50-60 cm or 5 to 8 year old).

Outlook

The landings for 2001 were revised downward, especially in the light of official statistics concerning the recreational fishery. Landings were reduced from 886 t to 253 t. The current assessment indicates that the mature biomass has decreased by 26% since 2000. At current productivity, the fishing pressure is unsustainable.

Overall, year-classes produced after 1993 are less abundant. With the low size of stock combined with the weak recruitment, total catches of more than 1 500 t in 2003 are projected to result in a further reduction of the spawning segment. Catches of 7 000 t (the TAC since 2000) are projected to produce a 12% decline of the mature biomass. A 5% target for growth in the mature biomass could not be achieved without a moratorium (Figure 13).

The mid-term outlook (5 years) suggests that declines in spawning stock biomass are highly likely. Rebuilding of spawning stock biomass is unlikely even without fishing. A strong recruitment event, which is highly unlikely under present conditions, and / or a large decrease in natural mortality would be required to change this outlook. The stock biomass is projected to decline by 36% if the current TAC of 7 000 t were maintained over 5 years.

Spawning stock biomass is estimated to be below the conservation limit reference points for this stock. There is a high likelihood that the productivity of stocks below the conservation limits has suffered serious harm. Given our current knowledge of the productivity of this stock, the chances of obtaining good recruitment is severely reduced when spawning stock biomass is below about 200 000 t. The current situation is well below this level in 2003 even in the absence of fishing.

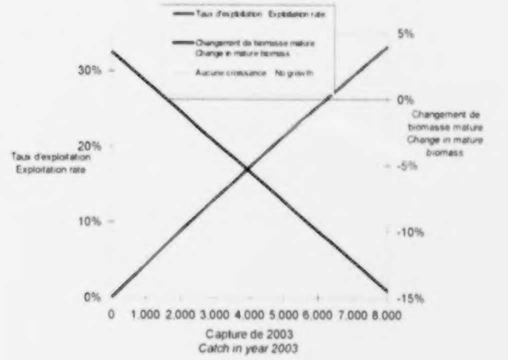

Figure 13. Harvesting rate and projected variation in mature biomass relative to various catch levels for 2003.

We currently have little knowledge of the stock productivity in the range of 100 000 t to 200 000 t. With more information of stock productivity in this range we will be able to revise the estimates of the biomass conservation limit. It is likely that the level will fall between 100 000 and 200 000 t.

Management considerations

The examination of the quality of landings from gillnets in 4R indicates that a high proportion of fish are in such poor quality that they cannot be processed for human consumption. Even if this catch is accounted for in the TAC, it represents nevertheless an useless mortality.

The current assessment indicates that cod mature at moderately old ages, and only 50% are mature between the ages of 5 and 6 years. Gillnets and longlines have a selectivity which targets primarily individuals of eight-year-old and over, so most cod can spawn at least once before being vulnerable to these fisheries. The current assessment indicates that 646 000 individuals of this cohort were fished at eight years in 2002, on a total cohort number of 1,8 million individuals. This fishing pressure is not sustainable.

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Annex 6

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FANL Position
3Pn4RS Cod - 2003 Quota

Issue:

- Establishment of quota level for 2003 and beyond. Reconciliation of the disparate views of industry and DFO Science, and consideration of the FRCC's recommendations.

Background:

- Science survey results for Northern Gulf Cod are showing a decline in stock abundance; minimum trawlable biomass levels however, have increased in both the Needler survey and in the July sentinel mobile gear survey.(p.7, SSR)

- There are widespread concerns regarding the validity of the Needler survey in 2002, including performance of the gear (many tear-ups) and problems with the SCANMAR equipment (resulting in only 50% coverage in 2002). It is also suggested that cod were more abundant in shallower waters in 2002 and possibly outside the surveyed depth range.

- The stock mixing issue between 3Pn4RS and 3Ps is requires resolution. This issue has been flagged by industry and the FRCC for several years. An otoliths analysis conducted by DFO Science in collaboration with the FFAW would have shed some light on this issue. Unfortunately, DFO Science was unable to complete this work, reportedly(A. Freshet, FRCC consultation, Port aux Basques) because of an inability to source the requisite $14,000.

- Sentinel surveys in 2002 for mobile gear and for fixed gear used a different method(p.7, SSR) for selecting the number of fishing sets to be conducted in a survey strata. Also, there was very limited observer coverage on these surveys(only a few mobile gear sentinel trips were observed) leading to a diminished view of their reliability by DFO Science.

- The commercial catch rates (from logbook data) for this fishery are not included in the model for 2002. Commercial catch rates have been showing progressive increases since the fishery reopened in 1997. The reason given for their exclusion, in a letter to A.O'Rielly from Dr. Wendy Watson-Wright, received April 8,2003, is that DFO has not had the resources to keypunch this data and incorporate it into the analysis. The exclusion of this data clearly jeopardizes the credibility of the assessment. The completion of this work would have gone a long way to resolving the conflicting perspectives of science and industry. Commercial catch rates at or above 2001 levels would bolster the view of industry regarding the health of this stock. There is little doubt that the logbook data would have shown high catch rates, given the results of the Retrospective Catch Rate Index (Figure 6 of SSR). Note also that this index was not used in the stock assessment. .

- The widespread view of industry is that the stock is healthy, abundant and widely distributed. The discussion on page 2 of the SSR acknowledges that environmental conditions have improved for Cod in the Gulf and that the biological condition of the Cod was evaluated in the Needler survey in August (page 4) where the four measured indices "are considered good and indicate an increase for 2002". A stock that shows improved and strong length at age, weight at age and age at maturity is hardly showing distress. Catch rates are at unprecedented levels leading to a strong industry consensus that quota reductions are not warranted .

- A modified risk analysis carried out by Mr. Alain Frechet following the FRCC meeting at Port aux Basques shows that the stock assessment model used by DFO Science is highly assumption prone and sensitive to modest changes in input values. For example, a reduction is natural mortality from .4 to .35 would enable a maximum harvest of 4,000 tonnes rather than 1,500 tonnes without risk of a reduction in stock biomass. The mortality factor of .4 is derived qualitatively and appears to have no analytical justification.

Position:

- FANL and other west coast groundfish processors recommend that:

- DFO establish 2003 quota of 5,000 tonnes (minimum requirement for a commercial fishery);
- outstanding work from 2002 including the Otoliths analysis and the commercial catch results be completed as soon as possible.
- shortcomings identified with the Needler survey be addressed to ensure a more credible ~~undertaking in 2003~~.
- all recommendations by the FRCC, other than the recommended quota level for 2003, be implemented immediately;
- a rigorous analysis of the stock mixing issue between Areas 3Pn4RS and 3Ps be undertaken in 2003 including the use of a 'counting fence' methodology to fully resolve this uncertainty;
- pending completion of the 2003 stock assessment, a multi-year recovery strategy be developed and implemented in consultation with industry.

This recommended course of action enables the continuance of a modest commercial fishery for 2003 while providing science and industry the additional time needed to resolve their competing views of the status of the stock. The proposed harvest level and the use of ultra conservative harvesting methods means that our recommended action carries minimal risk of negative resource impact . The research needed to undertake this work and address industry concerns is not expected to involve additional financial cost. The low resource risk and financial cost of our proposal must be weighed against the extremely negative social and economic consequences of a 'de facto' closure of the 3Pn4RS commercial fishery.

FANL
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December 20, 2002

Mr. Pat Chamut
Assistant Deputy Minister, Fisheries
Department of Fisheries & Oceans
200 Kent Street
Ottawa, ON
K1A OE6

Dear Mr. Chamut:

The Fisheries Association of Newfoundland and Labrador Limited (FANL), on behalf of our groundfish members on the West and Southwest Coast of Newfoundland, is very concerned about the position that DFO has taken regarding the 3Pn4RS cod fishery. The news that this fishery is being considered for closure in the upcoming year came as a shock and would be a devastating blow to our member firms and to the communities in which they operate.

Before a final decision is made regarding this stock and to enable a thorough analysis, we request that the Department supply us with information as outlined below. We are providing two series of issues for your consideration and response. The first set of issues are based on an examination of previous assessments of this stock and relate to issues that we feel are not satisfactorily explained or are in need of further attention. Those matters should be addressed in the upcoming stock assessment early in 2003. These major issues are as follows:

1. The Needler survey index, as input into the ADAPT model, has had several format changes in recent years (with and without the 1990 data, using only "carefully sampled" strata, and with the inclusion of estimates for non-sampled strata). Another option which should be considered is the exclusion of data for 1991. This value is substantially higher than the other estimates and is strongly influenced by three strata. It is also much higher than the Gadus Atlantica index value for the same year. The impact of the method used in the 2002 assessment to estimate values for non-sampled strata also appears to be more substantial on the 1991 estimate than for other years. The impact of inclusion and exclusion should be determined by the model diagnostics.

2. The Sentinel mobile gear surveys began in 1995. In 1997 the trawls used in the surveys were standardized particularly with respect to net opening because differences had been found. The assessment model should be run without these early years (1995-97) because they are not strictly comparable over the whole time period relative to net configuration.

3. The determination of mature stock biomass is and will be an important issue. Future target levels for stock size will most certainly center around the spawning stock size. The method

used to estimate these biomass values has varied in recent years (1998-2002) and there appears to have been changes over time. However, it appears that the most recent field observations available for this purpose have been those from 1998. We feel that it is important to use data available from annual field observations for mature biomass estimation.

4. With the exception of one year (1 999) assessments in recent years have used a value of 0.40 as an estimate of natural mortality in the assessment model. The basis for this value, as applied to all ages, needs to be revisited to determine whether it is currently the best estimate. It was originally used in place of the standard 0.20 because mortality estimates from research surveys, in the absence of fisheries, had suggested a high natural mortality. Seal predation has been cited as the main factor in this increased mortality although it has also been stated that seals eat mostly precruits (cod aged 1-3). Survey mortalities could be looked at again as they had been for the original derivation of the 0.40 value.

5. Information was provided in the 2002 Research Document on fixed gear catch rates from log books deployed on vessels less than 45'. There was no record of this data indicated in the resulting 2002 SSR. If this information is considered to be representative of stock status, we would recommend that it be incorporated into the upcoming assessment.

Our second set of issues and questions have been derived from consultations with our member firms and are based on their observations regarding the health of the stock and their observations on the conduct of scientific and commercial surveys. These issues are grouped in the following categories: Surveys, Commercial Fishery, Overlap Issues, Adjacent Stocks, and Natural Mortality.

Surveys

There are several surveys that are used to assess the health and abundance of cod in the 3PN4RS stock. These include a survey by DFO Science using the ship the Alfred Needler, and sentinel surveys conducted throughout the year by mobile and fixed gear fishermen, using various types of gear technology.

Regarding the 2002 Alfred Needler survey, we have the following questions:

- It has been brought to our attention that during the survey there were many problems with the gear, that on at least 12 occasions the gear was retrieved tangled and unable to fish. Were the tows in which these gear foulings occurred excluded from the data set?
- Are the coordinates used in the survey tows consistent from one year to the next with regard to location and timing?
- Are the number and duration of tows each year for the survey consistent with previous years?
- Is the vessel equipped with gear monitoring technology such as Scan Mar that allows the vessel operator to see if the net is operating properly?

- Is the methodology used to compile and analyze the data consistent from year to year?

Regarding Sentinel Mobile Surveys:

- It is our understanding that there are nine commercial fishing vessels used in this survey, and that their net sizes differ depending on vessel. Are the nets used for the survey standard as to type, size, mesh size and rigging, etc. Are the restricted door openings appropriate to allow consistent data comparisons?
- Are these vessels equipped with gear monitoring technology?
- Are adjustments made to the gear for fishing in various depths of water?
- Do the vessels fish in all depths of water, only water of a certain depth, or in the most likely depth that fish will be found?
- What is the method of payment for these vessels, and could that payment method cause the results to be skewed?
- Are survey tows where/when fish are not expected to be in an area included in the data for use in abundance estimates?

Regarding the Sentinel Fishery Fixed Gear surveys:

- In the Hook and Line Survey, are the number, size and type (eg.# 12 Circle hook, # 16 J-hook) of hooks used consistent over time?
- Is the type of bait and portion size consistent for the Hook and Line Survey?
- Are the areas fished consistent from year to year?
- Is the mesh size of sentinel gillnets consistent, over time and fisher?
- The Sentinel survey was initially introduced as a method to assess the health of the Cod. It appears that it has been used as of late as an index for cod abundance. Has the purpose of the Sentinel Survey changed? Is it now used to assess abundance?
- Are the catches of Sentinel boats monitored? Are there any checks and balances to ensure that the results are not skewed? Are observers required onboard Sentinel vessels?
- Is the Saturation Point (the point at which the gear is incapable of catching more fish) taken into account when using fixed gear surveys as a determinant of abundance? (i.e. the maximum amount of fish 1000 hooks can catch is finite, one fish per hook).
- Are soak times consistent for fixed gear surveys?

- For surveys taken outside the normal seasonal migration of the species, is the data collected excluded from the overall assessment? (e.g. hook and line surveys in 3Pn in January/February).

Commercial Fishery

Each year after the moratorium, since 1997, a commercial fishery has been conducted on the 3Pn4RS cod stock. For each of those years, information should have been available to science from the commercial fishery. Please confirm that this data has been compiled and explain how the data has been incorporated into the Stock Assessment.

Questions concerning the Commercial Fishery:

- Is data collected from the commercial fishery regarding species condition, abundance, and distribution?
- If the above data is collected, why isn't it used in the assessment of the stock? If it is not collected/compiled, please explain why such an important data source is not utilized.
- In 1992, when fixed gear fishers lobbied to have the fishery in this area (3Pn4RS) closed due to very low catch rates they were ignored for over a year. Now, these same fishers report record landings with the small amount of gear they are allowed to use. Why is scientific observations/assessments so radically different from the commercial fishing experience?
- It is known that discarding takes place at sea when gillnets are used, yet nothing has been done to document this problem, assess its impacts or take remedial action. Please comment/explain.
- What assumptions are being made about the amount of gear used to prosecute this fishery? What is the basis for these assumptions and what level of confidence exists as to their validity?
- Although dockside monitoring is available in most ports, there are still numerous ports where dockside monitoring is not required. These ports are very likely contributing to incomplete landing data?
- There is abundant evidence within the industry that catch rates are actually much higher in some areas than is evident from catch data. Many fishers when faced with too much fish on their gear or in their nets choose to pass the fish to another boat fishing nearby rather than discard. This practice has been observed by monitors. Is incomplete/inconsistent monitoring of catches a factor in assessing the commercial catch results?
- During the October/November quotas, catch rates were reported as high from Rocky Harbour to Burgeo. This represents a very large area, suggesting a broadly distributed and dense population of cod.

Overlap Issues

Prior to the moratorium, the 3Pn4RS cod stock seemed to over winter in the 3PN area. This pattern changed, probably within two years preceding the moratorium, and catch results suggest that the stock migrated further south and east of 3Pn during the winter. This change in the migration pattern has affected both the times that fish show up in certain areas, and the access fishers from the traditional area have to the stock, as well as access fishers from the area to which the stock.

Questions regarding the Migration of this stock to 3Ps:

- In 1996 a study was completed on the otoliths of fish surveyed to the South and West of St. Pierre Bank. It was concluded that out of the estimated biomass surveyed of 105,000 metric tons ninety five percent (95%) was Northern Gulf Cod. What surveys have been carried out since then to determine how far south the Northern Gulf stock migrates?
- Is the mixing discovered in 1996 taken into account for opening/closing of the 3Ps fishery?

Adjacent Stocks

We understand that the 2J3KL stock has seen only declines or zero growth since the moratorium. Fishers in that area have problems catching their 7000 pound yearly allocation. In the Southern Gulf, 4TVN area, we also understand that the fishing results have been poor for several years. The stock in the Northern Gulf stock has not seen such poor catch results. Up to 2002, the stock was showing modest signs of growth, and fishers not only had no problem catching their allocations, but fisheries were opened and closed quickly given DFO concerns that the quotas would be overrun every year. Almost no seasonal quota that opened this year lasted for more than ten days. Note that a 150 tonne fishery opened in 3PN in early November and lasted only 30 hours before the quota was taken. Catch rates were better than had ever been seen. This was a hook and line only fishery.

Given the huge differences in commercial catch results in 4R3Pn relative to adjacent stocks, our member firms question:

- Is the Northern Gulf Cod Stock really in such a terrible state that closure is warranted, or is it that this stock is located between two failing stocks that makes it more vulnerable to being considered for such drastic action.

Natural Mortality

The natural mortality numbers used by science to determine a stocks size are very important to the final estimate of stock status. There are several questions we have regarding the number used for Natural Mortality:

- The number used by science for natural mortality has been changed several times over the past few years, from to 0.2 to 0.4. One year, the amount of fish estimated to be consumed by seals was used. What is the rationale behind changing the number used for natural mortality, and how is seal predation calculated into the number?

- Is there any scientific information on how much cod seals are capable eating, and if so, why is it not used as part of the analysis of biomass.
- Why is an expansion of the seal hunt not being considered as part of the recovery strategy for Gulf Cod?

As can be seen by the above, we have many questions regarding the gathering of data, the use of data, the consistency of such data, and the usefulness of some data for purposes other than that intended.

We have witnessed an increase every year since the moratorium in the catch rates of cod, and the condition of cod has been improving each year as well. Fixed gear fishermen are seeing increases in catch rates and improved condition in the fish. This raises concerns as to the extreme differences in the perceptions of DFO Science and the fishing industry as to the stats of this stock.

As processors that depend on this stock, we are committed to ensure that this stock is harvested at a sustainable level, using the best possible methods to provide for optimum quality and with minimal adverse impact on directed and incidental species. If closure is the only way this can be achieved, we deserve to convinced of its necessity. As noted above, we do not agree at this point that closure of this stock is warranted.

We look forward to receiving your response to the points noted above. We note the importance of having these issues examined well in advance of the stock assessment meetings. On this latter point, we also suggest that an Atlantic-wide (zonal) review of the status of this and other groundfish stocks would be beneficial in ensuring that the assessment process is as comprehensive and rigorous as possible. The decisions emanating from this year's review will have profound consequences for the industry and the communities in which we operate.

Sincerely,

Alastair O'Rielly
President

AOR/amt

c.c. FANL Members
Fred Woodman, Sr., FRCC
Wayne Follett

DATE:

MEMORANDUM TO: Art Willett
Executive Director
FRCC

FROM: Jake Rice & Denis Rivard
Co-Chairs
Cod Zonal Assessment Meeting, 2003

SUBJECT: **MEDIUM TERM PROJECTIONS**

In Mr. Woodman's letter to Minister Thibeault of December 30, 2002, a request was made for "medium term stochastic projections" for the stocks recently assessed at the Zonal Assessment meeting. This request was discussed extensively during the planning leading up to the ZAP, in order to come up with simulations that were of sufficient scientific standard and consistent with the information available. At the ZAP it was agreed to forward the projections to the FRCC in a separate memo, rather than include them in the SSRs, for the reasons outlined hereafter.

The results of the projections are in the attached figures. Aside from 4 VsW cod, the scientific experts and the ZAP agreed that adding stochastic variation around the central trends would be unhelpful, and possibly misleading. The uncertainties quantified in the assessments represent only a portion of all the uncertainties in the future trajectories of these stocks. Therefore the range of variation in stochastic simulations would underestimate the range of outcomes that actually encompass how much further the stocks could continue to decline, or begin to increase, over the coming years. Deterministic projections, on the other hand, do convey as accurately as the science permits, the expected typical trajectories of these stocks. We stress, however, that "as accurately as the science permits" should not be over-interpreted. The projections should be considered illustrative of the medium-term possibilities for these stocks, and not indicative of a particularly likely future state of the stocks.

The message is clear in all cases. Major improvement in these stocks are not expected in the medium term. In the absence of fishing, spawning biomass of the inshore portion of Northern Cod (2J3KL) is expected to increase somewhat over the coming few years, as the 1999 and 2000 year-classes mature. Although these year-classes are the largest since the early 1990s, they are still extremely small compared to the historic productivity of this stock. Once these two year-classes have matured, the projections suggest that spawning biomass of the stock will show only marginal further increases, under current patterns of productivity and natural mortality. Even over another decade the spawning biomass is not expected to reach the size attained when fisheries were re-opened in 1998. Spawning biomasses of both Eastern Scotian Shelf (4VsW) and Southern Gulf (4TVn) cod are expected to decrease slightly over the medium term, even in the absence of fishing. Spawning biomass of Northern Gulf cod (3Pn4RS) might increase in the absence of fishing, but the increase would be marginal. All stocks are expected to decline if exploitation continues; the larger the fisheries the greater the further declines.

Interpreting these projections should take into consideration the work tabled at the ZAP regarding the conservation limit reference points associated with serious or irreversible harm to stock productivity. This information in included in the attached table. Aside from 4VsW, for which conservation limits were considered for the first time at the ZAP, these conservation limits were identified at the national Workshop on Gadoid Reference Points, in November 2002. The ZAP confirmed that all the workshop values are still valid as working values, given the most recent assessments.

These reference points are one of the cornerstones for how the Precautionary Approach is being implemented in fisheries management globally. The estimates considered at the ZAP also are all consistent with the federal framework on the application of precaution in Canadian government decision-making. This framework is in the final stages of being readied for endorsement by Cabinet, currently scheduled for submission in May 2003. Within the federal framework, decisions are to be highly risk averse relative to limits associated with serious or irreversible harm. Consequently, with spawning biomass for all four stocks estimated to currently lie below their respective conservation limit reference points, further declines in these stocks are of serious concern. Any management decisions that increased the likelihood of stocks not rising above their limits in the shortest possible time could not be considered consistent with the Precautionary Approach.

The framework for application of precaution may have substantial relevance to upcoming decisions on conservation and management of Atlantic cod. The Oceans Act directs that the Precautionary Approach shall be applied broadly by the Department. Also the COSEWIC Operations and Procedures Manual highlights that COSEWIC recommendations regarding listing should reflect a Precautionary Approach to conservation; a provision referred to frequently in COSEWIC deliberations.

I hope this information is useful to the FRCC in the discussions that it will be having on this important and challenging issue.

Jake Rice

Denis Rivard

Attachments

Table: Estimates of Conservation Limit Reference Points for spawning biomass and current stock status for these cod stocks. Although single numbers are tabled for current SSB of some stocks, we stress that all current SSBs are estimated with substantial uncertainty, as reflected in the risk plots and text of the SSRs. The uncertainties in current stock status do not alter the general pattern that all stocks lie in the zone where the risk of serious or irreversible harm to productivity is high, not low.

Stock	*Current SSB (tonnes)*	*Conservation Limit Reference Point*
2J3KL	Less than 50,000	Between 300,000 and 800,000 t. With little historic information on stock productivity in this range of SSB, as the SSB rebuilds between 150,000 and 300,000 t, information on stock productivity may allow the limit to be determined with greater precision.
3Pn4RS	39,000	Around 200,000. With little historic information on stock productivity between 100,000 t and 200,000 t, stock recovery to SSB greater than 150,000 t may allow the current limit to be revised.
4TVn	72,000	80,000 t
4VsW	1,000 – 4,000	Not finalised at the workshop. Estimates tabled at the ZAP indicate a range from 12,000 to 25,000, depending on method. Further analyses may reduce this range, but all possible limits are far above current estimates of SSB.